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RAILWAYS IN THE EAST

AND

ALL HIGH THERMOMETRICAL REGIONS.

A PRACTICAL TREATISE ON THEIR ESTABLISHMENT, THE DIRECTION OF WORKS,
MATERIAL AND LABOUR, EARTHWORKS, WORKS OF ART,
AND SECONDARY WORKS.

BY

illiam

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RAILWAYS IN THE EAST,

AND GENERALLY

IN HIGH THERMOMETRIC REGIONS.

INTRODUCTION.

MOTIVE—GENERAL OBSERVATIONS ON THE COUNTRY—REQUIREMENTS—ROADS—IMPORTANCE OF EVERY DESCRIPTION OF LATERAL COMMUNICATION.

THE East, and more particularly the rich and fertile plains on the shores of the Mediterranean and Black Sea, which constitute so large a portion of the wide and almost unrivalled dominions of the Ottoman Empire, have lately attracted so much attention in the European Railway world, that the writer of the following pages ventures with much diffidence, even after many years' experience as an engineer, to attempt making an analysis of the conditions under which the construction of railways, the management of works, and the development of such undertakings have to be carried on in the East and in the only partially inhabited districts of those regions; conditions of climate varying very widely, we all know, from that of temperate Europe; conditions of men, their habits and capabilities, and of a multitude of circumstances, in all of which the differences from the analogous state of things in the great territory of railways are broadly delineated, and are fully as important as regards railway construction and future successful results to shareholders as can well be conceived. Necessarily these differences in the conditions of so many important matters, bear equally on all large engineering works in those countries—such as canals, roads, docks, or irrigations—intended to develope the traffic of a country or otherwise improve it, where a large number of men must be employed, and where the traffic, to be commensurate with the great expense involved in such an undertaking, has to be opened up by every possible means that can be thought of; and probably they will be found to bear on all important works in climates, where generally the temperature attains such a high range, compared with that of Northern and Central Europe, as to be possibly the primary cause of the great differences which exist under so many aspects.

The writer wishes to submit to engineers and others, whose labours have not yet led them so far from home, some few practical observations which he has made during the performance of his professional duties, and which, merely relying on the value fairly attributable to the experience of every man, he hopes and ventures to believe may be of some slight use to all who are interested in these undertakings, either by the anxious duties of supervision, or through their having made investments in such enterprises, the uncertainty of which must naturally cause some anxiety.

The attempt is not made without considerable reluctance on the part of the writer, from his having an earnest feeling that there are many whose pens would be much more able to do justice to a task of which he fully appreciates the difficulty; but having been persuaded to undertake it, he can only endeavour to compensate for want of ability by being the more assiduous in his thoughts, by the most complete truthfulness, and the sincerity of his desire to render some assistance to those who, year after year, may have to follow in the path which he has himself gone over before, where they will find their energies very fairly tested, many anxieties to bear and difficulties to contend against, in order to do that justice to their responsibilities which every true engineer is determined to perform at any cost.

As in everything else, railways are made up of their constituent details, and it is in the difference of the conditions affecting these, that railway construction and the management of works in other climates, differ from the same description of work in the more highly civilized and temperate portions of Europe. Many of the works are very dissimilar in character, many constantly recurring on European lines occur but rarely in the countries now under consideration, whilst several of those which are *here* of only inconsiderable magnitude, assume features of the first importance *there.*

In the one case we can generally command almost any amount of the best workmen, skilled and unskilled; they are experienced in their work; they are in every sense completely under control, and move with almost as much regularity as the parts of a well-constructed piece of machinery; the amount of supervision they require is inconsiderable, and we know almost to a moment when it is needed. In the other it is generally the reverse, more particularly at the commencement of operations; we have almost always to do as best we may *in the early stages of construction,* with a very limited amount of most inefficient labour of every description, unless imported. The work is generally totally new to the men we have to employ, and they are often very unfitted for it by their previous habits, and perfectly innocent of any idea of system or discipline, or of the value of combined labour. These unfavourable conditions continue until the evil is gradually alleviated, and the difficult task of training partially performed by Europeans, who have at first the greatest difficulties to contend against—to unteach and teach anew—and who, unfortunately and most unwisely for all parties, are not always selected on account of former experience, ability, or character, but often from classes utterly disconnected with the work to be performed. In itself and under any circumstances this is a great evil to contend with, and one which very soon makes itself severely felt—but in the case of that description of labour, and under the conditions to which we now refer, it is of incalculably damaging influence, and every day's work bears the stamp of that inefficiency and confusion which exist in the mind of the man who is attempting a task which he has never seen performed before. *Here* such instances of incapacity are very soon remedied by speedy detection; *there* too many causes hold good for a remedy to be easily attainable, and the evil has to be counteracted, as much as may be, by infinite labour and anxiety, and endured always with loss to those most deeply interested. When this occurs at several places along a line of works, no supervision from head-quarters can control the mischief.

It is, however, very different with an able European ganger or foreman. The raw levies we have to lead are far from unintelligent or unamenable to discipline; although generally frivolous and devoid of the European's energetic intent of purpose, they are perfectly capable, after a time, of being directed in the right course, and of performing a very fair amount of labour. They are speedily far-seeing enough to ascertain when they are well-directed, and ready to respect an able leader, and to obey him; but, like other beings, they are prone to feel great contempt for incapacity. They are obedient to a rule of calm firmness, but sulky to extreme and vindictive towards that brutal violence which is too often exerted against them. Although perhaps, as a rule, working men in Asia generally are of a somewhat slighter frame than in most parts of North and Central Europe, they are frequently met of large stature and vast muscular power, capable of performing any of the heaviest railway work.

Good materials of many descriptions and for various purposes are often as scarce as good labour, unless imported also, and we do not always meet with such intelligent arrangements that such importations are made with the truest economy in every acceptation of the word. It is true, however, on the other hand, that where native materials are adapted to the purposes they are required for, they are obtained and worked after a time very economically. When, however, such is not the case, the engineer must bring all his skill to bear to obviate any evil results arising from such cases, often by great changes in the disposition of his materials or of his works, and he will often have to give up his mind to new features in construction on this account, the more earnestly from the necessity of his keeping before him the hard fact, that by whatever difficulties he may be driven into a failure, he must nevertheless bear the blame—for it is everywhere a special feature of our calling that what we cannot effect by one means we must by another. Those who rule at home over undertakings carried on in distant climates ignore the word difficulty even more resolutely than at home, and the term impossibility has long since been practically expunged from the dictionary of the engineer.

Unless the undertaking be commanded on all sides by ability and intelligence of a superior order, with judgment and forethought capable of establishing wise provisions at an early stage of the works, even our most hardy Europeans, to whose value as skilled pioneers and leaders it would be difficult to do justice—men inured to hardships all their lives, leaving their respective countries intent on meeting and prepared to overcome them—men who gather knowledge still more valuable than they possessed on their first arrival, by acquiring experience as the works proceed, suffer so much daily, in every sense, that health often breaks down, and with it all mental energy, and men of hitherto good character, become totally demoralized, even to an extent incredible here, and quite unfit for and incapable of duty; many of the latter scenes of their lives have been, to the writer's personal knowledge, too fearful to relate.

It has been thus that, in far too many instances, men whose skill and experience brought from Europe had been ripened into greater value by knowledge of the language, of the habits and capabilities of the men they had to lead, and by many local technical advantages, to be acquired by residence only, have become lost to the Contractor and the Company. It would be futile to attempt disguising that scandals and discredit, seized upon with avidity by intriguers of every description, and most deeply felt and very candidly acknowledged by the most sincere well-wishers of the undertaking, are consequences sure to arise. They are of much deeper injury to all the vast interests engaged than is generally contemplated. The very reputations first damaged, and the most seriously, are of those who stand at the head of the enterprise. To assert that these results must attend every such undertaking in the East is surely a fallacy which means, if anything at all, that all such enterprises in the East must be failures, and warnings that they are to be avoided.

In the great railway territories of Europe it occurs but rarely that we find any serious deficiency of good roads for the forwarding of materials; on the contrary, in Turkey and in similar regions, where the roads are generally, except in the immediate neighbourhood of large towns, but primitive tracks, the traffic on which is transported by camels, pack-horses, mules, &c., the subject of means by which we may push the works forward is one deserving of much consideration from the first, and one that can only be neglected at great present expense, and infallibly with the most fatal consequences to the Company hereafter.

When we consider the great expenses incurred on account of the Contractor's staff, as well as that of the Company, how desirable it is to open up to public traffic any section of the line as spedily as possible, in order to obtain a return upon the large capital invested, and, of far more importance in the end, give the most substantial proof of the value of the undertaking to the inhabitants of the country, the great importance of breaking ground in as many places as may be judiciously done, becomes self-evident. But this cannot be effected unless provisions are made for the purpose. During the rainy season, little or nothing can be done to the roads; but as soon as the genial spring of those latitudes and their early summer have fairly set in, the ground dries and hardens very rapidly. Many improvements may then be effected with an inconsiderable expenditure, so as to render the roads passable in defective places for moderate quantities of materials carried on light vehicles adapted to the roads and the beasts of burden that may be procured; contracts may also be made with native carriers, for the forwarding of such materials as may be got forward by their mode of transit. By these means, combined with two or three others to be treated of hereafter, the energies of the contractors and of the company's engineers are more widely available, and the plant is not locked up on a short length or division of the works. More important still, a delay of a year or two may thus be avoided, much to the shareholders' advantage, and the gratification of a native population, who often express their surprise that with all our boasted energy and activity we do not manage to push on our works somewhat more rapidly, and that what we do accomplish is not at least somewhat better done than they could manage themselves.

In such countries, the subjects of roads and means of transit from the stations to the towns in the neighbourhood of the line are also of great importance to the traffic to be brought on to the railway; not only ultimately, but immediately after its opening, when the shareholders, native merchants, landowners and cultivators, as well as the inhabitants generally, and the Government from whom in all probability we are still seeking great favours, are one and all anxiously watching to note what changes and improvements the iron way will effect. If judicious measures have been taken beforehand, so as it were to lead the way for the public mind to enter gradually on the new phase which the ordinary road traffic must assume in connexion with the new railway, then these changes and improvements will be speedily developed; but otherwise, it will be found that very inconsiderable advantages will be gained even from large towns, from which a considerable traffic was originally anticipated, and might readily have been obtained, if by a little forethought, arrangements had been made to adapt the old general conditions of the ordinary road traffic to the new and special feature of railway transit.

All men of experience know that when the public mind has once refused to adopt a new order of things, it is afterwards a work of time and patient labour to lead a whole population to agree to and enter upon that for which they have contracted feelings of aversion or ideas of inconvenience. But the introduction of improved roads and modes of transit, and of tramways where the traffic of a town is important enough to admit of it, leading to the railway stations, and gradually formed, more or less simultaneously with the railway works, would ensure very different and much more beneficial results than those which have frequently been obtained; the proof of this is demonstrated in the history of all European railways, more especially those of earliest date. It would also be found that until mismanagement had created apprehension of failure, Government would be prepared to grant readily all possible encouragement, facilities, and privileges for the establishment of these communications from important centres of population and trade to the railway stations. The writer entertains strong convictions that all negotiations relating to these come more immediately within the province of the Company itself; that negotiations should be entered upon at an early stage of the works by the chiefs of the administration, and in order that the Contractor's attention and energies should in no wise be diverted from the heavy responsibilities of the railway contract, that the light works involved in the formation of these roads should gradually, and as convenient, be undertaken by the Company's officers.

The importance of every description of communication that can be made between the railway and the surrounding country laterally is sufficiently established, not only by good authorities upon the subject, but by the most intelligibly expressed requests made by the Government as to their requirements in the following *Cahier des charges* and in the Concession. Art. 82 in the former is intelligible enough on the subject; nothing can be more explicit than Art. 3 of the Concession, which is one of the most important Articles it contains, and treats of nothing but branch communications. They are perfectly aware that a main line of railway by itself, and without the assistance of lateral communications must be unproductive either to the Company, or the country traversed, and point distinctly to the means by which such results may be avoided. If we take any one of our own great railways and cut off the complete and perfect system of ways leading to it, we shall have a parallel from which to draw inferences. The establishment of such roads as we have in France or in England is no more requisite than a fine display in the stations. Simple economical utility is the requirement of the country as well as of a railway company to meet present demands.

Another important matter demanding the earliest and most earnest consideration of engineers and all the Company's officers is that of obtaining the widest possible local information from as many sources as are available; a variety of, and often conflicting opinions, all, however, having some grounds for their adoption, must be carefully sifted and examined, and then judiciously tested. Roads, traffic, passes amidst hills or mountains, labour, population, materials, all must be as closely and assiduously examined as circumstances will admit. We can scarcely listen to too much, from the fear of missing perhaps only one portion of valuable information. We must take nothing for granted, but test everything to the satisfaction of our own knowledge. This is an engineering law, even in districts of which we may fairly suppose ourselves generally cognizant; *à fortiori,* is it to be attended to in strange and wild regions of which we do not know even the general features or capabilities, and still less the multitude of details which are connected with them. Of the greatest importance is all the information that may be gathered relating to the water level attained during the rainy season generally, and years of exceptional floods, which usually occur at about every four or five years; and this not only as regards the flow of rivers to be crossed by bridges, and streams by culverts, more especially in hilly districts, but also the water-levels usually, as well as occasionally, attained throughout the low countries and valleys to be traversed by the proposed line of works. In countries where a depth of rain, equal, at a low computation, to about six feet, occurs very often within a period of six weeks or two months during a rainy season, and sometimes more, the writer having known of a fall of upwards of ten inches in one night, instead of some thirty or forty inches rain-fall during the course of a year, it will be readily conceived that rivers and streams become flooded to such an extent, and so suddenly, that they require very different treatment to that which they receive in cases more generally within the practice of the European engineer. From the want of reasonable attention to this, we have many instances on record of bridges being carried away, embankments severely damaged, with the natural consequence of dangerous settlements in the permanent way, culverts choked up or destroyed; the whole involving costly expenditure in the renewal, or a patching up, which is by no means edifying to the people who witness the work of destruction and *repair* (?), and which never fail to give rise to the most injurious comments and the most dangerous doubts and suspicions. Again, from the want of reasonable attention to local information and a proper examination into the subject, a line of rails for many miles and during several months has been so submerged that either the works have been entirely stopped, or the traffic suspended during such period, and at seasons when it was most urgent to carry large quantities of goods; from the same cause storehouses have been flooded, and large quantities of property damaged or destroyed. Not only such events lead to great pecuniary loss, but they give rise to deep suspicion of the ultimate failure of the undertaking in the minds both of the people and the governments, of which we should so anxiously and so sedulously seek the respect and esteem. However disagreeable, we must admit that it is not without good cause, when we come to consider that these evils might have been obviated by moderately reasonable attention to evident causes, which were sure to bring about such disastrous results if not properly considered.

Serious as we must admit these facts to be, of graver importance still are other consequences of the neglect of local information, and of a reasonable study of circumstances fully open to investigation, when we find expensive stations built where they are not required, and trifling and insufficient buildings erected where the traffic becomes most developed; large sums of money cast away in commencing tunnels, which practically, under circumstances, are almost impossibilities, from their demanding a vast outlay and eight or ten years for completion; expensive jetties constructed in comparatively shallow water for the supposed accommodation of an immense amount of shipping from all parts of the world, and employing for such a purpose timber unprepared in any way whatever, notwithstanding every description of warning, and with evidence patent to all along some mile or two of wharves, that it was doomed to certain destruction by the ravages of the worm in the course of a few years, which might be counted almost to a certainty. The writer trusts that on this subject he has said enough to establish all the importance of local information, and the necessity for the careful investigation of all advice that may be offered to him.

The reader will not fail to perceive that in the above observations many of the subjects referred to come within the ordinary range of the engineer's practice, though often greatly modified by considerable differences in the conditions under which they offer themselves; the writer hopes, however, that much remains that will tend to explain, at least to some extent, how much the duties of professional practice differ in populous Europe from the same avocations in those regions of the East which have not yet been visited by the locomotive, or where it has done so but very partially; that some idea may be formed of the difficulties which an engineer has to overcome in the climates and countries now referred to; of some of the new elements in management which have to be brought under control, some of the new conditions and circumstances which he has to consider and deal with; of things to obviate or totally avoid.

In the following pages they will generally be treated of more in detail. For several reasons, there are many subjects to which, although of deep importance in those countries, the writer would hesitate even to make any allusion whatever, if it were not that either he entertains deep convictions regarding them, that he has seen great events arise in consequence of them, or that his experience has amply satisfied him that many of the evils mentioned are to be provided against—doubtless with some trouble at first, but ultimately with results of the most important and beneficial character—largely to the profit of the Contractor, to the welfare, credit, and honour of the Company, and with loyal justice performed to the Government granting the Concession, generally replete with the most liberal clauses; leaving, at last, but conditions to be easily controlled and work to be readily performed, when judgment and a fair amount of forethought have been brought to bear upon the production of the new appliances, or of the modifications of old systems required by a new state of things. There remains, it is true, the great heat of a fine climate, which is, however, far from being without its many special advantages, and although trying under several respects, many influences beneficial to the great undertakings of railway construction may be derived from it, if proper provisions are made. Few have enjoyed the brilliant sun of the East, the gorgeous and generous vegetation of those fertile regions, with their magnificent and romantic scenery, and the cheerful hospitality of the inhabitants, without feeling a deep and earnest desire to return to it.

In these introductory remarks there is but one more subject to call attention to as regards railways in the East, before coming to deal, though not entirely, with the dry facts and figures to which the expression of "Engineering," in its general acceptation, is more usually confined—certainly very erroneously, at least in those climates, for to accomplish his task, the engineer will find that he requires other assistance than that which he can obtain from his level and theodolite, mathematical calculations and drawings. The writer will ever be the last to refuse admitting to the full extent all the importance deservedly due to these, and he has sufficiently insisted upon them elsewhere; but in these regions, so distant from the immediate rule of the chiefs of the administration and the influence of public European opinion, it will be found that in many instances the mechanics of the hearts of men appear to assume, as it were, a new power of action, and that they are far more difficult to "engineer" over than mere matter. In his new position, and the new scene he enters upon, he will find a great variety, and some of no mean difficulty to control in the *foreign* state of things; that very many subjects besides "setting-out" demand thought and attention, earnest and unwearied in proportion to the interest he takes in the success of the undertaking, and of *those for* *whom he is working*, and *from whose means he is paid.* It will be upon many of these, besides mechanical arrangements, that observations will be made in the following pages. To many large populations, great undertakings, and vast interests, the most fatal consequences have been produced by neglecting to pay attention to matters of *common sense*, and which, naturally, we can only attribute to mismanagement; fatal consequences, which it will take many a long struggle to overcome.

It is a very commonplace, but none the less valuable observation to repeat, that it is deeply to the interest of the Governments of all the countries to which we now refer to obtain railway communication. They are perfectly cognizant of all its importance in opening up the wealth of vast provinces, now completely shut out from the commerce of the world, although possessed of the means of untold abundance, which the population have every desire to dispose of. The Governments are also perfectly aware of the special political advantages which they would derive from a system of railways leading down from the interior to the coast. They give undeniable proof of the earnest interest they take in the subject by the liberality of the conditions of their Concessions. A handsome guarantee on eight, ten, and fifteen thousand pounds sterling per mile for the works and rolling stock connected with a single line of way, generally through a country where the works of construction are of the most unimportant character for the whole length, or some five or six-tenths of it; the free grant of all Government lands, and when purchased their value is the merest trifle, except in and about important cities; the import of all materials duty free; quarry, timber, and ballast rights from the rivers, free also; liberal rates, absence of competition, and the whole traffic of the country secured, if reasonable provisions are made to secure it; a wide district to range over in the selection of a good line, perfect freedom from the powerful influence of great landowners, so often antagonistic in Europe to the economical direction that might be given to a line of railway, and from the often extravagant demands successfully made for purchase and for accommodation works; besides a host of other privileges, for a railway passing through districts almost always rich and fertile beyond belief, with the power of production, even to affluence, of the very commodities of which civilized Europe is most in demand, either running down to the sea-board or from one populous town to another, are surely fair and liberal conditions.

Such a grant constitutes an undertaking on which capitalists may enter very profitably, and in which it might reasonably be expected that the public would gladly join. The causes which lead them to withhold from doing so, even when invited by men of the greatest ability and most ample means, of the very first character, reputation, and responsibility, are surely deserving of a searching investigation. It must be conceded by reasonable minds generally, that if circumstances similar to many of those recorded above were to occur on railway works in Europe, they would not win the good opinion of thinking people, but would arouse public indignation. In the East, those who are interested in railways are neither torpid nor indifferent as to what becomes of the means they may have invested; they are on the spot, anxious and watchful, and with the most satisfactory means of ascertaining how the works are managed and carried on; their common sense, which is of a very shrewd nature, enables them, exactly by the same mode of reasoning we should adopt ourselves, to foresee success or failure at an early stage of the works. It is not flattering to European enterprise, energy, and talent, when, surrounded by every encouragement and the most promising conditions, they only accomplish a great disaster; such a catastrophe is much to be deplored, not only as regards the ruin of one or two great enterprises, in which the shareholders had a right to anticipate a very different result, but because of the baneful influences it so powerfully exerts on any future great undertakings of the kind.

Should these pages have the good fortune to lead the reader to trace some of the causes of failure, and some means by which more favourable ends may be obtained, and thereby help, even to a slight extent, to restore some of that confidence to which railways in the East are justly entitled, the writer will have attained all his desires; for on those fertile plains there is vast wealth to be gathered by those who are intent to do reasonable justice in making the railways by which, at no distant period, they must be traversed.

CHAPTER I.

REVIEW OF DIFFERENCES IN THE CONDITIONS UNDER WHICH RAILWAYS HAVE BEEN CONSTRUCTED IN EUROPE AND THOSE UNDER WHICH THEY HAVE TO BE MADE IN THE EAST—DIFFERENCES IN THE NATURE OF THE WORKS—THE ROAD TRAFFIC.

In order to convey an approximate view of the special conditions under which railways have to be constructed in the East, it will perhaps render this subject as intelligible as it may be made, if we request the reader to carry his attention to the analogous conditions as we find them in those countries where railways have already been largely introduced, in addition to numerous roads and canals, and where we are possessed of all the advantages arising from a high state of civilization. Perhaps the comparison will be somewhat nearer the reality if we review matters as they existed some twenty years since, when railways were comparatively few. We shall still find that, even then, we had all the advantages of numerous good roads and canals passing by or to and from large towns and villages in the proximity of any proposed new line, and which were never very far apart from each other; from these, large populations of the labouring classes, experienced more or less in all the crafts of construction, could be drafted off at any time to carry on the works.

We possessed so complete a command of materials of every description that we could never be much at a loss as to securing anything that might be required; every description of brick, stone, timber, and iron, of all qualities and dimensions, whether for ordinary or special purposes, was generally to be procured at very short notice, and always to be obtained in a few days; the quantities first required, from towns and villages in the immediate vicinity, prior to larger quantities being forwarded from special districts. In most cases these materials could be deposited close by workshops, where men and every description of tool were in readiness to shape them for their ultimate destination, and generally not very far from the site for which they were intended, and to which, even when the materials were of great weight, there were ample means of transporting them. The towns and villages afforded dwelling room for the workmen to such an extent that in most cases only an inconsiderable amount of hutting was comparatively required for their shelter; where, however, there was any deficiency of house accommodation in proximity to the works, stringent special clauses were made for sufficient healthy hutting, and our best Contractors vied with the Company's officers to make it as efficient as possible, knowing that the men required at least as much care as the horses.

The more ample we found the above-mentioned resources, the greater we were assured would be the traffic we should obtain after the opening of the line. When the towns and villages were numerous, we knew we should have also numerous goods and passengers to carry for them, and as a rule, by these and the number and quality of the roads, we could approximate to the quantity of traffic we should be able to bring on to the rail.

In addition to all the advantages we have above mentioned, we must now add those arising from the absence of destructive epidemic diseases, and from the presence of abundant medical assistance in cases of sickness or accidents.

If we now take a map of France or England, and draw a line from any town on the coast to some hundred miles or so inland, consider all constructed railways and canals as effaced, as well as nine-tenths of the towns and roads for some thirty or forty miles on each side of the proposed line of railway, we shall be able to form some idea of many of the conditions under which railways have to be established in the East.

It is, however, to be carefully noted, and always kept in view, that as regards capital expenditure on account of construction of works, where we have no roads to cross, we shall have no road-bridges and expensive level-crossings to construct and maintain; and even that where these works are found necessary, they are not of so costly a description as in old railway countries, on account of the nature of the local traffic, which, however it may be improved, will always partake to a considerable extent of its present character.

In the absence of numerous large towns and villages, we shall require a comparatively slight station accommodation, the buildings for which, with all their contingent accessories, and first-class road approaches, form a large item of expenditure on European lines. Except at a few particular points, it will be found that the station accommodation required will be of the most simple and inexpensive character. In the absence of nine-tenths of road-bridges, level-crossings and station buildings, the heavy expenditure for these will be proportionately reduced when proper management is adopted. In the absence, also, of important towns and villages, and of powerful landowners, as well as by the wide range always granted under the Concession, the engineer is at perfect liberty to select almost any route for the adoption of the most economical line that can be laid out—by which means, of course, very many expensive or dilatory kinds of works may be avoided.

Having regard to traffic only under the circumstances we are now considering, it is to be observed that the districts to be traversed by railways are, almost without exception, of truly wonderful fertility—a fact which is sufficiently evinced by the state of the lands under cultivation—that the produce is almost all of the most valuable kind in the European markets, and that the absence of cultivation in many parts is to be attributed solely to the want of means of transport; this has already been sufficiently proved by the lands opened up at once in the immediate vicinity of a part of a railway delivered up for public use. At present large tracts of lands, which might be made of great value, remain uncultivated solely because the present means of conveyance is so slow, so troublesome, and so expensive.

This will be readily understood, when we come to consider that at present the only means, almost entirely exclusive of all others, is by camels, pack-horses, and donkeys. The following memorandum made of the average daily traffic for one week, coming from the district of Magnesia and Cassaba along one main road leading into the town of Smyrna, will afford a very fair idea of what at present are the means of transport in Asia Minor. From 8 A.M. to 8 P.M., there passed at one particular point 2125 camels, 1360 donkeys, 1070 horses, 57 carriages.

It will now be understood, that in the construction of a line of railway, we must, on the one hand, lose by the absence of all those advantages which arise from the existence of numerous good roads and populous towns and villages; on the other, we must gain by having to construct a much smaller number of works of art, and being enabled to avoid many heavy earthworks, bridges, and other constructions, which, in Europe, circumstances would compel us to build: the loss we must endeavour to make as slight as possible, and our gain as great as may be. The hope of pointing out some of the means by which this may to some extent be effected, has induced the writer to undertake a task which he feels to be onerous, and for which he earnestly seeks the kind indulgence of his readers. He trusts, also, that he will be able to show that, in this new railway territory, great advantages are to be reaped by those who undertake railway transport, if a due amount of consideration be given to the conditions and circumstances by which the railway will at first be surrounded, and which all the officials will have an arduous task to contend against. From these few observations, the reader of railway experience will probably have already observed, that both as regards railway construction and railway management, the *local* features will demand some amount of thought, in order to apply the means best suited to obtain the most advantageous results, and to combine efficiency with economy, that great desideratum of all great undertakings.

CHAPTER II.

NATIVE LABOUR, SKILLED AND UNSKILLED—MASONS, CARPENTERS, SMITHS, QUARRYMEN, AND NAVVIES—MANAGEMENT REQUIRED.

In the neighbourhood of the terminal site on the coast of any proposed line of railway, it is more than probable that we shall obtain satisfactory labour, sufficient to carry on works of an ordinary character for some short distance forward, immediately after operations are commenced—such as earthworks, provided they be not very heavy, getting out foundations, and common masonry, always, however, excepting good archwork, piers, quoinwork, and other masonry or brickwork of a character fit for even plain but substantial railway structures.

The greater portion of this, for some time at first, if any degree of speed and quality is to be attained, will have in great measure to be done, and all superintended by competent European workmen, mostly French, Swiss, or English, and it will be generally some little time before they can come to an understanding with native workmen on the subject of technical terms, and as to the manner in which masonry suitable for public works has to be done.

It will be found mostly that the only kind of masonry these workmen understand is a rough kind of walling, which, however, with some additional labour and trouble, may be made to pass with extra thickness in the backing and counterforts of bridge abutments, in retaining and wing walls of quite an ordinary character, in foundations and common walling, and where the work is not submitted to any particular strain.

Anything else is at first beyond their skill, from the simple reason that they have never seen any kind of superior workmanship, such as our ashlar and block-in-course, and still less of our brickwork.

They have only very loose ideas of the courses, joints, beds, backs, and bond of stonework or brick workmanship, and it is therefore needless to say that they have not the faintest notion of 'skew work: all this arises naturally from the fact of their never having had any necessity for the masonry which Europeans introduce into their public works.

Their churches, bazaars, baths, and large dwelling-houses, are built of *very thick* walls of coarsely fitted rubble, generally tied together by a coarsely-jointed framework of timber, mostly of small scantling; and when quoins are introduced, it is in such a manner as would anything but gratify a good European mason.

It is, therefore, sufficiently evident that we shall here require some skilled workmanship, more particularly that of good bricklayers generally, which we must learn to combine as economically and efficiently as possible with native labour. It would, however, be very bad policy to discard this latter altogether, as the result would be a much larger and expensive importation of European labour than would, in fact, be really required. Besides, we should, by doing this, lose all the opportunity of training the native masons, and thereby ensuring, after a short time, the most economical description of labour we can hope to obtain.

On the subject of mason's work, it must be carefully kept in mind that all along the towns on the coast, and in very many cases to some distance inland, there are a great number of Greeks who are highly intelligent and perfectly capable of being taught, and who but for want of good opportunities would be very fair workmen. They are certainly completely ignorant of all the rules and practice of ancient Grecian art, but if taken into a little patient training, become, in a short time, able masons for plain work, both stone setting and dressing.

In this matter the mistake too frequently committed is to insist on too large a quantity of work at first, so as not to leave them time to learn. It would be found a much wiser course, and far more economical in the end, to consider these men under a short apprenticeship, as it were, so that they might have opportunities to learn, and acquire some practice in the handling of our European tools, as well as in regard of the characteristic features of construction adopted more particularly in public works, of which they are completely ignorant.

It must be admitted by any one who has had experience amongst them, that they are very intelligent, most ambitious of acquiring some of the skill of European workmen, and proud of achieving any such success. As a rule, they are quite as industrious as any of our own people; almost always of great sobriety, but naturally impatient when their employers, generally European or Levantine sub-contractors, urge them, roughly enough it must be admitted, to perform a new kind of work, with tools of which they have had no experience, with as much rapidity as our practised workmen; or when, under these circumstances, they are driven to accomplish an amount of work, equal in volume to that which they had been accustomed to perform in their own way.

They then become simply careless and indifferent; for not being a numerous class of men, they are perfectly alive to the fact that either we must employ them, or make expensive importations of European skilled labour.

Much more advantageous it would be found if, at first, these men were to undergo a month's careful and patient training on the works, under the superintendence of good European workmen, and allowed to do nothing but good work. We should then very speedily form an able body of workmen, by which means, for many reasons, we should in the end effect a great economy: this is obvious enough from the mere consideration that we should thus mould to our purposes a number of men who would have all the advantage of being accustomed and inured to the peculiarities of and the contingencies incident to the climate and country.

They then could be advantageously drafted off, according to their competency, to join in the works entrusted to sub-contractors. It would prove much more satisfactory to the Company's works, and assuredly more profitable ultimately to the Contractor.

Such a course would besides obtain the earnest approbation of the Government, who are most anxious to introduce new or improved industries into their country.

In respect of carpenters, it will be found that similar observations bear on this trade also, whether it be rough ship carpentry, or carpentry and joinery. Their notions of straight arrises, plane surfaces, tenoning and morticing, and all jointing, are of a very primitive order; but except, perhaps, for very highly-finished work, they may be trained even more readily than the masons.

Of any able body of smiths there is a greater deficiency than of masons and carpenters. Fitters must all be European, but they will soon be able to train some of the more intelligent native workmen to do the more laborious part of their work.

The Ionians, who generally speak English more or less, speedily become good stokers, and will in time become also good engine-drivers.

Good quarrymen are to be found in sufficient numbers, to the extent at least of blasting rock, and as far as the procuring of stone from the quarry; but they are excessively rash, and require strict supervision to prevent numerous fatal accidents. If they are entrusted with the squaring out of the blocks, they will at first require to be carefully looked after, for otherwise they are very likely to do this work as though the stone had to be set on edge instead of on its natural bed. After a time they do their work very well in a rock cutting, and require merely the same amount of direction which would be given, under similar circumstances, on European works.

The true craft of the regular "navvie," in anything like a deep cutting and leading to tip for forming an embankment, does not yet exist in the Ottoman Empire. Light earthworks, such as shallow cuttings and embankments from side cuttings, may be done very fairly under the direction of a good ganger, and very economically, on account of the low wages. As a general rule, however, the men are by no means the vigorous fellows we meet in Europe, and there is always a much greater proportion of youths in a gang than we are usually accustomed to meet: this arises, of course, from the necessity of getting as many hands as possible on to the work.

For these reasons, I am satisfied that there would be a considerable economy effected in reducing the size and weight of the tools and implements, more particularly of the barrows; what with the heat of the climate and the average strength of the wheelers, it is very rare that our barrows are more than one-half or even one-third full.

This observation will hold good, more especially when the earthworks are performed by labourers taken from the Greek population, but it will also bear pretty generally as regards the Turks themselves. Although, as I have observed elsewhere, there are amongst them men of athletic strength, who carry loads which would astonish a European porter, these men usually secure so much better work as hamals, or porters, in the large towns, that we do not get many of this description about the works; those we do obtain are generally more profitably employed in quarries, about stone and timber yards, or where there are heavy loads to lift.

Gradually the number of workmen of every description and trade increases, and there, the same as amongst us here, they often come from very distant points, generally solicited to do so by old comrades, who often keep up distant communications as to various matters on the new works.

A review has now been made of the principal crafts required in carrying on railway works, and indeed of most public works generally; and it will be seen that at first some little management is required to bring them into training; it is, however, nothing more than that which may fairly be expected in a strange land, and when the men come under the management of skilled European workmen, a very little time and patience produce great results, provided always that both the foreman and the workmen meet with the considerate forbearance which the new circumstances demand.

CHAPTER III.

NECESSITY FOR SPEEDY COMMENCEMENT OF WORKS UP COUNTRY—CONSEQUENCES OF NEGLECTING DOING SO—NATURAL WEALTH OF COUNTRY—STATE OF ROADS, AND THE GREAT IMPORTANCE OF THE SUBJECT—MATERIALS—CAMPS AND LABOUR-STATIONS—ADVANTAGES, PRESENT AND FUTURE, FROM THEIR ESTABLISHMENT—HUTTING FOR WORKMEN—PROVISIONS—FEVER, ETC.

THE greater number of workmen who will offer their labour after the works have been fairly commenced will enable us to break ground on further lengths; the accomplishment of this, we must hasten forward, by all possible means, unless we intend a dilatory execution of the new railway, which must prove unsatisfactory to the Company, unprofitable to the Contractor, and a disappointment to the Government, who entrust these works to Europeans in the expectation that our experience and energy will accomplish them with some reasonable speed.

This disappointment will be followed by consequences of even graver importance than those of the expensive plant of the Contractor being locked up on some short length, or of the officers of the Company's staff being prevented from bringing into action that amount of exertion which might be rendered useful on a more extended line of operations.

Every reasonable amount of patience and forbearance, we may very safely calculate on receiving; but when the Government itself and the native population, who are all anxiously watching our actions, perceive unnecessary delays, confidence soon begins to be shaken, and many at once wish to retire from the undertaking; others, who were only waiting to gain a little experience before taking a pecuniary interest in the enterprise, congratulate themselves on having withheld from doing so.

Some amount of well-disposed, straightforward, and regulated energy, in a course previously investigated and then determined upon, would produce the reverse of these unfortunate results. It is a very fatal error, which those who claim to belong to the more highly civilized nations are sometimes prone to fall into, that they think themselves so highly "policés," as to be warranted in a system of subterfuge intended to deceive those from whom they are receiving every kindness and indulgence, and who are, they forget, quite as competent as themselves to form a sound judgment on matters of common sense only. The ill consequences of pursuing such a course will make themselves to the full as severely felt in the East as well as in Europe, whether it be in following a system of delay and frivolous excuses, or one of *mistakes* and bad workmanship: the depth of the fall achieved in public opinion will irremediably be in the proportion of the high estimation formerly held. Such, however, must be the result attained, if, after a full amount of time has been taken for consideration, procrastination and delay usurp the place of a fair amount of energy in carrying the works forward: under the circumstances now before us, some amount of forethought is required.

The description already given of some of the local features of the country, will make it evident that provisions will be necessary in order to render this extension of labour of any efficiency further inland, and to do so with economy. We shall find no brickfields, no stone or timber yards, no smithies to have recourse to for materials or assistance in the means of drafting them on to the works. A few trifling hamlets, inhabited by small populations, whose labours are wholly in request for the cultivation of the surrounding fields, are all that we shall meet with, perhaps, within a radius of eight or ten miles; from these, it will be evident that we can hope but for slight assistance. Their little villages are not of sufficient importance to provide either shelter or food for one tithe of the men who are about to commence new portions of the works.

We must be careful, however, that these observations do not in any way mislead even the casual reader. The real value of the lands for the purposes of the cultivation of produce of the greatest importance in the commercial world, must not by any means be estimated by the fact that the populations in the midst of them are small. It would be difficult even to imagine a greater error, or one more likely to lead into mistaken appreciation of everything in the East, from beginning to end.

Much greater power of language than the writer can command could alone do justice to the effects of the climate on vegetation: its surprising activity will perhaps be fairly represented by expressing its influence on the life of ephemerides; many genera which, even in the southern parts of Europe, continue their existence for several weeks, last in these countries not more than ten days or a fortnight: they suddenly appear in great numbers, fulfil the purposes for which nature has intended them, and then quickly disappear.

The same rapid power is exerted on every description of vegetation, the quick, strong, healthy, and productive growth of which, even notwithstanding a great deal of very indifferent cultivation, is surprisingly great. There are immense vineyards, with the vines to a considerable extent growing almost wild, the stems and fruit lying about on the ground, often amongst weeds: the grapes of these are, for size, fulness, and saccharine matter, far from equalled even by the vineyard gardens of central France.

It is the same with regard to every other produce, and the above has only been selected from amongst others for a more general explanation to Europeans. The depth of rich vegetable soil on the plains is equally surprising, and is constantly evinced by excavations; the writer, in sinking pits in search of ballast, &c., has generally found three and four feet deep of rich vegetable earth.

No land can be more fertile in the production of the silkworm, the seed of which is exported annually in every direction in large quantities.

Immense herds and flocks graze over the plains, and in the spring and early summer would do honour to any European grazier; but they suffer in the height of summer solely from the want of improvement in the lands, where irrigation is greatly required.

It is a fact beyond a doubt, that the finest descriptions of American cotton may be cultivated most successfully over many large tracts of this fertile empire.

Could communications once be established, such as a through single line of railway, from a good harbour town on the coast, say some hundred miles in length, with twenty or thirty miles on each side for its special territory, one or two branches and tramways with proper appliances for working them, and a few of the main roads rendered merely workable—we should very soon find some one or two thousand square miles of country under cultivation, numerous mills, and factories for silk, woollen, dye and tanning works, for which these countries have special industries.

Always remembering, as regards the whole of these constructions, that we do not require, in the countries now referred to, anything approximating in magnitude and expense, to such works as we find in our great European lines, and in our populous manufacturing districts; such, for instance, as the London and Birmingham or Lancashire and Yorkshire railways, or such as the Chemin de Fer du Nord, or du Midi; nor such branches and tramways as we find in our mineral districts; nor such roads as our turnpikes, or grandes routes Impériales; that to construct such would simply be lavish extravagance and waste of capital; that we should not require numerous trains—some moving over the country at sixty miles an hour;—remembering all this, and how inconsiderable need be most of the works, and how many privileges are granted under the concessions, any practical man will admit that twelve or fifteen thousand pounds per mile on the length of the railway itself, with a guarantee from the State, are ample means and security to do all that may be required;—keeping in mind also, that the rates are most liberal, and that the more valuable goods are light and of comparatively small bulk, but requiring protection and care, such as are offered by improved modes of transit, and will therefore pay the best; there can be no doubt that such an undertaking must be most profitable for those who engage in it.

The writer truly believes that the first Company which accomplishes such a line of railway with ITS BRANCH COMMUNICATIONS, may very fairly depend on the support of the whole Ottoman Empire.

As in these pages reference will often have to be made to the roads, the above observations will always be referred to to prevent the possibility of any misunderstanding. At present, our business is to make the railways and roads, and we will return to the subject-matter more particularly in hand.

It will now become a question of the first importance, how the men are to be sheltered, and also how tools and implements are to be got forward: this last will soon be disposed of, but the question of the men demands some explanation, and some investigation of numerous subjects in connexion with it. We shall not only have to consider the disposal of the men, how they are to be managed, provisioned to their own advantage, and therefore to the advantage of the works; we shall also have to consider how we are to procure building materials.

It has always been an object of anxious care with our great engineers, and one which has always obtained all the consideration they could devote to it, that the workmen engaged on great public works should be properly taken care of, and that they should have justice done to them.

It has not been their maxim, where men engaged on their works have been enabled to lay aside something from their labours, that such works in a financial sense had been mismanaged.

They have always been anxious that they should be justly paid and sheltered, and taken every pains to ensure that these things should be so.

The policy of thus protecting the men, on whom alone we are depending for the accomplishment of a great undertaking, is too evident to need any argument to substantiate it.

Many of our leading engineers insist on no hutting of any description whatever being allowed on any part of the works, but require that decent and sufficient lodgings shall be provided.

If the necessity exists for provisions of this character in populous Europe, it certainly must be much more imperative that so important a subject be attended to in those portions of the countries now referred to, which are entirely denuded of the means of affording the men any shelter, and where therefore we cannot stipulate for lodgings. Provisions are only to be obtained some miles from the works, insufficient in quantity and of most indifferent quality; the most unjust advantages are often taken through this means to the injury of the men.

The ordinary necessaries of life are commonly carried a great distance to the works, perhaps thirty or forty miles, and in one way or the other the men charged exorbitant prices. This is often done to such an extent, that they prefer procuring food of any description as best they may; and their bread is often such as Europeans would not give to their dogs.

These things soon become publicly known, excite great indignation, and the blame and scandal are always laid at the door of the Company. The people are unaccustomed to the means by which great public works are carried on in Europe: they have but very faint notions of drawing distinctions between Company, Contractor, agent, sub-contractor, foremen or gangers, or those in any way connected with the works: in their opinion, any one on the works represents the Company, and a time-keeper is styled an engineer; they only acknowledge *the Company;* they consequently reap all the blame, which, however, it must be acknowledged, is not undeserved when there are simple legitimate means of avoiding it.

Amongst those for whom we are carrying on such extensive undertakings, there are many men, who if they do not know exactly how we carry on such works in Europe, are at least aware that there does exist a system under which these things are properly administered, and who do not fail to see, when these evil circumstances reach their ears, that we are taking advantage of their supposed ignorance.

When there are from seven or eight hundred to a thousand men, and perhaps twice that number, engaged along some twenty or thirty miles of works, who have to be provided with shelter and food in a district incapable of supplying more than a tenth, at the utmost, of what is required, and that with great uncertainty, it is evident that the subject becomes one of the highest importance to the Company.

The men themselves are not slow to perceive that they labour under circumstances the most disadvantageous to themselves, but of course do not examine whether either the Company or the Contractor himself reaps any benefit from their doing so. Instead of being anxious to remain on the works, they are only desirous to meet with an opportunity to escape. Thus men who had gained some experience are constantly lost to the Contractor as well as the Company. When such events occur on European works, the loss is more or less easily soon replaced; but this is not the case in the East. When we obtain fresh hands, we have again to go through the process of training before they become efficient, and the Contractor incurs even a greater loss than the Company or workmen.

Intimately connected with this subject is one of the characteristics of the climate, which is the fever of the country, which is more or less prevalent everywhere, but more particularly along the plains and valleys generally traversed by railways, still more so near marshes, and especially where large masses of earth are being freshly moved. The malaria arising from these is very dangerous. This epidemic is more particularly contagious for those who have to undergo great bodily and mental fatigue, and exposure to the heavy dews of the night renders a severe attack almost a certainty.

It often assumes a malignant character, dangerous to life when neglected or from improper treatment. Unless under very favourable circumstances, Europeans are always at first subject to attacks. In the vicinity of low-lying marshy districts, so great is the fear of it, that it is not unusual for whole villages to effect a brief emigration during the height of a sickly season.

On railway works, unless some judicious provisions be adopted, a severe and often dangerous attack is sure to prevail amongst the men. One of the most serious consequences resulting from it, is the low state of prostration to which the body is reduced, often for many months afterwards, even when the most generous diet is administered and every care taken; but when this cannot be obtained, as in the case of labouring men, the most powerful constitutions are broken down for a long time; many weeks elapse, occasionally six or seven months, before strength is regained.

There cannot be any doubt, when a large body of men, the only working-men to be had, is thus attacked, and a large proportion of them prostrated in strength for weeks afterwards, that it must make very serious inroads on the progress of the works; very few of the convalescent, after they return to their work, are capable of doing, for a considerable time, the same amount of work they were capable of accomplishing before the attack. This unsatisfactory state of things amongst a large body of workmen often lasts for weeks together.

Where such bad policy and such an erroneous system of economy are pursued, as to neglect proper and judicious means to protect the men from all the severity of this epidemic, it is a deplorable sight on walking along the site of some earthworks, to see scores of sufferers lying under a few branches cut down from some neighbouring bushes, exposed throughout the day to an intensity of heat almost tropical, and with no other shelter from the heavy dews of night.

Assuredly it would be useless to allude to this subject, if such evils were not to be obviated or largely mitigated; but when it comes to be ascertained that nine-tenths of these fatal results are to be prevented by a proper system of hutting, discipline, and management, it is surely as necessary to mention, as it is deplorable to see neglected, such a simple remedy.

The course which the writer, after anxious consideration of his own experience and of the best information, feels convinced should be adopted as a preventive and check, is the establishment of camps and labour-stations. Throughout Europe, even in its most healthy and temperate districts, some such measures are found imperative, and always adopted for the protection of labour, not only on the score of humanity, but from motives of the most wise policy.

No reason can be assigned why, for the very same reasons, it should not be applied in the trying climate of the East.

Throughout the greater part of the Empire, more particularly south, the weather is almost always fine for nine or ten months in the year, and nothing but the most simple and economical description of building need be adopted. Some of the happiest days the writer can remember were spent in the East, with no other shelter for the night than that afforded by something like a watchman's box, made of light quartering and thin boarding, and measuring 6 ft. 6 in. × 6ft. 6 in. × 7 ft., and which constituted a bedroom; another immediately opposite formed the establishment of a friend and colleague; the space between was spanned by a little roof formed of branches, and was our office and dining-room. One tent afforded shelter to the seven or eight men we had for chainmen, staff-holders, and labourers; a box or two constituted the larder, and the cook established his kitchen accordingly as the wind set in the environs. A couple of camels carried the whole from one "location" to another, for which work we contracted.*

To return to the subject of our men, it will be found that similar constructions, only of course on a more extended scale, would in most cases answer all the purposes required throughout a large portion of the empire.

In situations liable to greater changes of temperature, we should find ourselves either amongst or in the close proximity of mountain-ranges, where the hutting could be erected of rubble and coarse mortar, and often of sun-dried bricks. It would be found the cheapest way to get these buildings erected, to make contracts with the native workmen.

Only the most simple constructions would be required, and they would effect both present and future beneficial results. Whether light timbering, rubble, or sun-dried bricks be employed, the only materials required for such purposes as these, could all, or very nearly so, be procured about the locality, economically brought to the works, and put together. At the commencement of operations this could also be conomically done by contract: we should acquire some experience of al characteristics of labour, which is information never to be despised r any circumstances whatever, and judge of what improvements be beneficially introduced.

ay here be observed that all small bulks of materials, requiring ular care in the transport, are to be carried in these countries economy, the means being nothing more than droves of those d animals, the donkeys. Of course, our dignity as European contractors and engineers is certainly very much shocked *at first* by the mere mention of the services of animals with such slight personal dignity of appearance; but after we have read and learnt our lesson, and handsomely paid for it too, we discover that droves of these may be most usefully and economically employed in carrying stone, bricks, lime, sand, gravel, and fuel, &c.

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* This way of living is very far from being unpleasant, so long as fever keeps away; but it is very expensive, in consequence of the distance provisions have to be brought, and the servants to keep, and through waste which cannot be avoided. Engineers will find it necessary to have a special understanding with the Company by whom they are employed, on this subject, or they will find that they will lose considerably by being in the field.

The traffic by donkeys along one single road leading into Smyrna has already been mentioned at page 16: this formed but a small portion of those engaged in carrying in and out of other portions of the town. There has been of late years a very large number of stone-built houses in the course of construction every year in this city, which is so rapidly extending its influence in the East; two extensive conflagrations have besides swept away a large number of timber-built dwellings, which are being rebuilt of stone. All the materials for these, excepting the larger descriptions of timber required, which are hauled by camels or horses, are carried in panniers to the site of the works by donkeys only: thousands of them are thus daily employed throughout the year.

The traffic by these animals is suitable to the condition of the roads: they are very hardy, and require but little care, and are driven by boys: the climate thoroughly suits them; they are kept on little else than chopped straw; they are very intelligent, and after a few journeys know their road and their business as well as their drivers.

For distances of only a few miles, and for carrying loads which are of considerable weight though not bulky, on the roads which we find in the East, they are remarkably well adapted. The keep of horses in those countries is so expensive, that their abstemious rivals will always have the preference for carrying loads wherever they can be employed.

In concerting all the arrangements necessary for carrying on our various descriptions of works, we must constantly keep in mind the important fact of the roads being something very similar to our by-lanes in Europe. If they are not full of ruts, it is simply because they are never travelled over by heavily laden carts. To avail ourselves of these roads before we have done something to improve them where most required, we must employ the pack-animals employed in the country.

The subject of transport, more particularly at the early stages of railway operations, and before we have been enabled to establish improved means of carriage, is so important, that any economical means of effecting it should not be omitted in these pages. The writer will therefore make no further apology for introducing a subject so very much beneath our European dignity,—if it did not affect our pockets.

Whatever the materials we might find it most economical to employ, the construction of the camp buildings would generally, as regards capacity, be in proportion to the importance of the works on which their temporary inhabitants would have to be employed. When built of timber, they might possibly in some cases be fitted up with berths one above the other; when constructed of rubble or sun-dried bricks, we should probably have greater area and less height. Every building should have a division for a foreman or ganger, and one or two guards, with the most complete means of inspection from end to end. A trench should be excavated round the outside of every building. Men of different creeds should be kept apart as much as may be conveniently.

In establishing a camp, one of the most indispensable necessaries to be sought after is a spring or well of wholesome water; and it will be an additional advantage, though not one of great importance, if the camp is in the vicinity of a few plane-trees, this being Eastern luxury. Water, however, is the one great primary consideration, the presence of which should be sought after as diligently as the absence of the destructive "raki" should be persistently enforced: in spite of all we can do, more than enough will always find its way into the camp, and during the fever season it is particularly dangerous from its inflammatory nature, and the more so that the liquor supplied to the men under these circumstances is always of the very worst quality.

The water from the rivers is seldom so good as it appears: although in summer very clear, it is generally charged with organic matter, and the quantity which the heat of climate compels the men to drink, renders it dangerous; bad water brings on fever and dysentery also.

In all cases, the camp should be established, when possible, on rising ground, always provided that water be near, and at some short distance from earthworks, from which malaria always arise, with most injurious effects in unusually sickly seasons. One or two huts should always be supplied for the Company's inspectors.

When the works are light, such as surface-works, the camp buildings should be so put together as to be easily taken apart and transported from place to place, which will rarely occur more than once or twice in the course of a year.

Where heavy bridges, or viaducts, or important earthworks occur, the camp or labour-station will occupy a larger area. As much as possible in these cases, it should be established at no great distance from the intended site of a future station. Some small accommodation should be here supplied for the Company's engineers as well as the Contractor's sub-agents, and also for the Company's inspectors of works.

It will scarcely fail to strike the minds of Directors and shareholders, that the presence of their engineers is constantly required on such works, which is probably a reason why the writer has seen such accommodation sedulously avoided: he would suggest that in all contracts for these distant undertakings, special clauses should be introduced for the provision of these, according to the directions of the Chief engineer, in addition to the usual stipulation directing that engineering requisites shall be supplied.

It would be far better still, that these matters should be maintained in perfect independence, and that sufficient reserve be made to enable the Engineer-in-chief to have these little constructions erected for his resident engineers and inspectors independent of anything approaching the odour of favour: after all that may be said on the subject, a couple of thousand pounds would more than supply all that would be required in this way, over a hundred miles of line; on the completion of the works they could be profitably sold, or remain for the temporary accommodation of the Company's engineer, traffic manager, and other officers going up country, or for that of plate-layers, &c., in charge of maintenance. Unfortunately, in the East, as yet, we have been penurious of shillings and lavish of thousands of pounds—in this and many other far more important matters.

It will be scarcely requisite to observe that such a large body of men would require to be kept under discipline, and that a reasonable system of government should be framed for the purpose.

The most stringent regulations must be made and maintained, prohibiting the men being paid in any other way than in the current coin of the realm, and to prevent any one connected in any way with the undertaking, from supplying them with any description of goods, provisions, or liquors.

The appointment of all persons entrusted to supply the men must rest entirely with the Company, and it will be the duty of their officers to see that it is properly done. In many cases the market may be left open to public enterprise, and most advantageously so to all, merely requiring inspection on the part of the Company's officers, to protect both the tradespeople and the workmen. Many of the inhabitants of the towns some distance off would only be too happy to take advantage of the accommodation offered at the camps, and supply all necessaries required by a large number of working people.

In these countries the labourers, most particularly those who do the work of navigators, have no watches, and there are no church-clocks in the neighbourhood of the works to tell the hours of the day. The result is, that whilst a sub-contractor can contrive to overwork his men, a foreman or ganger does the reverse. To ensure some degree of regularity, every camp or labour-station should be provided with a large workmen's bell, which should be rung at proper hours.

In every respect, the nature of the country and climate is such, that only the most simple description of house shelter is required for the working population. The kind of timbering required for log huts may be obtained from the forests of the State, under the Concession, and through the tribes of wood-cutters, at a very low rate. In the neighbourhood of stone districts, rubble may be obtained in a similar manner; the poorer people, moreover, are accustomed to build their cottages of a common description of sun-dried bricks. Nothing precludes the possibility of adopting these most ordinary measures of care, and building up this simple system of hutting far more economically than it could be done in most parts of Europe.

If the reader will now review the conditions under which the labour of perhaps two or three thousand men is to be brought to bear on the construction of railway works, the absence of all shelter and provisions, and the nature of the climate, which, with native labour, is all in our favour where proper protective measures are adopted, but otherwise of a most deceptive and dangerous nature,—the writer hopes it will be admitted that too much could scarcely be said on this important subject.

It is confidently believed that the course of proceeding above proposed for adoption is perfectly practical even within the narrowest sense in which the expression may be received, and that it would produce both economy and efficiency. When precautions of this kind are not taken, it will be found a common occurrence to see a large proportion of the men absent themselves from the works full two days in the week, the assigned motive being to bring up provisions; it will be found also that we are constantly losing men, who do not care about remaining on works where so much privation is to be endured, and that they will demand higher wages before they consent to go up country. Establishments of this kind would secure the services of better men and of greater numbers. Ulterior benefits of no insignificant value to the undertaking would result from pursuing such a course.

Considering all the natural advantages conferred on this vast Empire, its fine climate, its immense fertility, and long line of sea coast, the proportion of produce exported to other parts of the world is very inconsiderable. It cannot be too often repeated, that this arises from the want of means of circulation, not as regards railways only and specially, but also from the general absence of roads. The population is scattered about in every direction, mostly in the smallest possible parcels. There are no great arteries for collecting it in masses in the most promising districts, and leading them down gradually by chains of intercommunication from the interior to the coast.

It would be a great object gained and tending in this direction, if any amount of population, with prospects of employment before them, could be gathered together in the neighbourhood of the sites of future railway-stations.

The establishment of labour-camps near such sites would effect this in a great many instances.

More particularly in situations where works of any importance would have to be carried out, some five or six hundred men would be gathered together, probably over a period of twelve or eighteen months. If properly camped, under a system of reasonably judicious measures, it would be found in a very short time that small markets would be established for their supply, always provided that the dangerous and fatal truck system be vigorously crushed out from amongst them, and if people connected with the railway be effectually prevented from making little fortunes by pursuing it at the expense of the men, at the expense of the Contractor, at the expense of the Company.

Not only should tradespeople be allowed, but they should receive every possible encouragement, to come and supply the men: they will be found perfectly ready to do so, where not systematically and often brutally driven out from amongst them: they will be found quite as industrious as ourselves where opportunities offer, and quite as alive as any amongst ourselves to the chance of making a profit. When they do not come forward to supply provisions, it is because some private system of nepotism or private friendship is persistently exerted to exclude them. This is often another subject of great scandal, and one successfully inviting a feeling of bitter animosity against the Company. It would not be allowed in Europe, and there are no other ground than injustice committed with impunity, and the unrighteous exertion of power, for the system being pursued on railway works in the East.

The establishment of these camps, as well as of these markets, where, we repeat, every means of attraction should be offered, and where some slight accommodation might be very judiciously tendered to attract and temporarily arrest the progress of caravans, even long before there were any signs of station-building, would soon induce some amount of cultivation. The gathering of these men, the collecting of these tradespeople, during the progress of the works and in such situations as railway-stations, would be a means of many settling down there altogether: this once effected in such a position, others would come and join them; there would be a motive, a cause, a prospect for the cultivation of lands, which naturally would follow as a matter of course incidental to the improved conditions of the country and even the limited wants of a collection of men: the landowners would be too happy to afford every encouragement.

We have thousands of instances of the establishment of European towns and large villages due to the rise of a railway-station; but every care was taken not to drive away those who were disposed to come and trade and establish themselves near its situation. There are far more reasonable causes for such occurrences in the East, if they be only fostered by giving fair encouragement and doing reasonable justice to the people who are disposed to join us, and amongst whom we are invited for purposes of improvement and not of commercial demoralization.

It would only be the duty of the Contractor to build, under his contract, the ordinary amount of hutting required for the accommodation of the men, the remainder would be the work of the Company.

No amount of difficulty would be found to exist that could not easily be removed, either as regards the Government or the land-owners; with the latter, however, it would be desirable to effect arrangements *ab initio.*

Many of the above observations will doubtless appear very novel to the engineer accustomed to European railway practice; some almost too trifling to deserve mention, and others will seem very arbitrary: but if the reader will be kind enough to bring his mind to bear upon all the conditions, which a very imperfect attempt is here made to describe, he will probably perceive that many of the recommendations which have been made on matters which would be utterly useless in Europe, become very important in countries denuded of population, and consequently uncultivated; a state of things which would be of very short duration, if these apparently small matters of common sense could only obtain the attention they deserve: he will also, no doubt, perceive how very requisite it is to establish provisions for the protection of labour.

CHAPTER IV.

"CAHIER DES CHARGES," OR SPECIFICATION OF CONDITIONS RELATIVE TO THE CONSTRUCTION AND CONCESSIONS OF RAILWAYS IN TURKEY.

I.—*General Direction of the Line of Railway and Construction of the Works.*

1. The Company constituted under the concession for a railway from —— to —— agrees to construct at their own cost and on their own responsibility, and to complete, within a period of —— at latest, from the date of approval of the general direction of the line defined in the following Article, all the works of the railway in such manner that it may be safely worked throughout at the expiration of the above-mentioned period. The railway will commence at ——, pass by or near ——, and will terminate at ——.

2. Within a period of —— from the date of the Firman of the Concession, the Company will submit to the Government a general "itinerary" showing the direction of the line, which will appear the best adapted for topographical requirements, and the general interests of the Empire.

This "itinerary" will consist of a plan drawn to a scale not less than $\frac{1}{100000}$ for a longitudinal section, and of a certain number of cross sections taken at the most difficult points; of a summary report as to the laying-out of the line with regard to the interests of Government and of the districts traversed, and giving an approximate estimate of expenditure.

3. —— months after the deposit of the said "itinerary," the Government will announce its decision, hearing being granted to the Company, as to the general direction of the line to be taken; if at the end of this period of —— months the Government has not announced any determination, the Company will be at liberty to proceed, and to consider the project submitted as approved.

4. Dating from the approbation of the general "itinerary" or plan,

the Company will submit to Government every three months and in sections of 30,000 *archines* at the least ($22{,}500^{m}\cdot00$ = about fourteen miles), plans drawn to a scale of $\frac{1}{10000}$, of the definite setting-out of the line of railway, in conformity with the features of the "itinerary" adopted.

The Company will show on this plan the situations of stations and sidings. Annexed to these plans will be added: a longitudinal section of the railway, a certain number of cross sections, including a cross section of the permanent way, a table of gradients, specimen drawings of the most important works of art, and abstract estimates as to the works.

The longitudinal section will be drawn to a scale of $\frac{1}{10000}$ horizontal and $\frac{1}{1000}$ for the vertical heights, which are to be referred to the mean level of the sea as datum; beneath the section will be shown the following, by means of three horizontal lines:—

a. The distances in thousands of archines of the length of the railway from its commencement.*

b. The lengths and inclinations of gradients.

c. The lengths of the straight portions of line, and of the curves with their radius.

5. During the progress of construction, the Company will not be allowed to make any alterations from the approved plans, either as regards plan or section, without having previously obtained the sanction and due authority of Government to such alterations. But in other respects the Company may introduce such modifications of details as they may consider requisite, provided always they adhere to regulations hereafter explained.

6. The lands purchased shall be sufficient for a double line of way. The earthworks and the works of art may be constructed for a single line only, with a certain number of sidings, and along the entire length, the rails may be laid for a single line with the exceptions of the sidings. But the works of art shall be so designed as to be adaptable hereafter to a double line of rails, without incurring great expense, and without any inconvenient obstruction to the traffic.

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* A scale of archines.

The Company engages to lay down a second line of rails, either along the whole length of the railway, or on those portions which will be pointed out, when the insufficiency of a single line of rails, through the development of traffic, shall have been declared by Government.

7. The gauge between the rails shall be of 1·92 to 1·93 archines (1^{m}·44 to 1^{m}·45). Where the line is double, the space between the lines, measured from the exterior flanges of the rails, shall be of 2·66 archines at the least (2^{m}·00).

The width of driftway, or of the space between the exterior of the rails and the outside of the ballast at the upper surface, shall be of 1·33 archines at the least (1·00).

8. The Company will construct along the whole length of the railway such ditches, drains, and benchings, as may be proper for the draining and maintenance of the permanent way and the works.

9. The portions of straight lines will be connected by curves of a minimum radius of 500 archines (375^{m}·00). A straight line equal to 133 archines (100^{m}·00) at least shall intervene between consecutive reverse curves.

10. The maximum inclination of gradients shall be of ——. A horizontal length of 133 archines (100^{m}·00) at least shall be introduced between any two steep gradients of contrary inclination determining the drainage to the same point.

The gradients shall be reduced as much as possible where the curves are of small radius.

The Company will be at liberty to propose any modification they may consider requisite on this subject, as well as relating to the preceding Articles; but these modifications can only be carried into execution after having been submitted to the approbation of the Government.

11. The sidings shall be in such sufficient number and so laid out, that no distance exceeding 30,000 archines (22^{m},500·000) shall intervene between any two of them; the length of a siding shall be at the minimum of 260 archines (about 195^{m}·00) including the return curve.

12. Between the sidings there shall be established along the length of the railway for the accommodation of local traffic, lateral sidings for loading and unloading.

13. Wherever the railway shall cross roads or footways, which it

will be requisite to maintain for local communication, these shall be crossed, as much as may be, over or under.

Level-crossings may, however, be constructed under such circumstances, when the locality does not offer conveniences for the construction of viaducts, under or over, without considerable expense, and without inconvenient obstruction to traffic.

14. When the railway crosses over a road, the opening of the crossing will be determined with regard to the importance of the road, and may vary between the limits of 4 and 10 archines ($3^{m}\cdot00$ and $7^{m}\cdot50$), according to the importance of the roads.

For arches, the height beneath the centre of the intrados shall be of 6·50 archines at the least ($5^{m}\cdot00$). Under straight iron or timber girders, the headway shall be of 5·75 archines at the least ($4^{m}\cdot30$.)

The width between the parapets of viaducts shall be at the least of ten archines ($7^{m}\cdot50$) for a double line of rails, and of 6 archines ($4^{m}\cdot50$) for a single line.

15. When a railway crosses under a road, the width of the road between the parapets shall be determined, according to circumstances, at from 4 to 10 archines ($3^{m}\cdot00$ to $7^{m}\cdot50$), according to the importance of the road.

The opening in a viaduct between the abutments shall be at the least of 10 archines ($7^{m}\cdot50$) for a double line of rails, and of 6 archines ($4^{m}\cdot50$) for a single line. The vertical height above the outside rails of each line for the passage of trains shall not be less than 6·40 archines at the least ($4^{m}\cdot80$).

At level-crossings of roads, the rails shall be laid level with the surface of the roads, so as to cause no inconvenience to carriages.

At all level-crossings there shall be a gate opening on the outside of the railway, and also a lodge, when required by Government, for protection of the public.

16. The Company will provide such measures as shall be requisite to prevent animals from straying on to the railway.

17. If, during the construction of the railway, it should be found requisite to divert or alter the levels of existing roads, the new inclinations shall not exceed 6 per 100 archines ($0^{m}\cdot06$ per mètre) unless requisite.

18. The Company will re-establish and make good all watercourses that may have been stopped or affected by the works.

In the case of bridges crossing over rivers, canals, or watercourses, there shall be at least a width of 10 archines (7·50) between the parapets for a double line of railway, and 6 archines (4^{m}·50) for a single line.

The height and waterway for the bridges will be determined in each particular case by the Government, according to local circumstances, on the representations made by the Company.

19. Where tunnels are requisite, they shall be at least 10 archines wide between the uprights at the level of rails for a double line of way, and 6 archines (4^{m}·50) for a single line. The height from the intrados to the level of rails shall not be less than 6·40 archines (4^{m}·80).

20. The materials used in the works shall be of good quality, and the works shall be executed according to all the rules of art, in order to ensure substantial construction.

The rails and other parts of the permanent way shall be of good quality, and of sufficient strength for the purposes required.

21. To the general plan which will be submitted in sections of 30,000 archines (22^{m},500·00) the Company will annex a return descriptive of sidings, level-crossings, bridges, and aqueducts, viaducts over or under the railway, and of the tunnels which it is proposed to construct.

22. Within —— delay Government will have made known its decision as regards the general plan, and all the designs submitted. At the expiration of such time, if no decision has been declared, then the Company may consider its plans as approved, and may proceed with the construction of the works.

23. The railway will be enclosed by walls, hedges, or such other fencing as may be requisite to prevent trespass, or the straying of animals.

24. All lands required for the railway or its dependencies, or for diversions of roads, rivers, or canals, shall be purchased and paid for by the Company.

But in the case of all lands not built upon, and belonging to the State, those portions requisite for the railway will be granted free of expense.

25. All compensation for the temporary use of, or damage done to lands, or for the stoppage, alterations, or destruction of factories or mills, or for all damage arising from the works, will be made at the expense of and paid for by the Company, with the exception, however, of any damage done on Government lands, for which the Company will not have to pay.

26. The undertaking being one of public utility, the Company is invested, for the execution of the works under the Concession, with all the powers which, by the laws and regulations, belong to the State, to obtain, carry, and deposit all earth and materials, under the condition that the Company shall indemnify all owners, by private agreement, or such failing, then under the regulations established for such purposes.

After the setting-out of the line shall have been approved of, the Government will take the necessary steps to proceed with the expropriation of the lands within —— after application to that effect made by the Company; to this effect Government will send an engineer and commissary, appointed to superintend the Concession, and such others as may be deemed requisite.

This commission will deliver to the Company the free grant of the Government lands traversed by the railway, and at the same time will cause the Company to purchase, under the law of expropriation for works of public utility, the private lands of which the transfer is required for the works.

27. Within the limits of frontier boundaries and the precincts of fortified positions, the Company will be under the obligation, in the study and execution of its projects, to submit to all the formalities and conditions which the Government may appoint. The same necessity will have to be observed wherever the line comes across monuments or buildings of public worship.

28. The Company will appoint its own agents for the execution of the works, subject always to administrative control and superintendence. The object of such control and superintendence will only be to the end of preventing the Company from deviating from any of the conditions prescribed under the *Cahier des charges*, or from the plans that have been approved of.

29. Accordingly as the works or parts of the railway are completed, so that they may be handed over for public use, steps will be taken by Government, by the appointment of one or several commissaries, to proceed to their reception.

On the receipt of the inspection documents, the Government will authorize, if necessary, the opening of such portions of the railway, after which authorization the Company may work the same, and may take toll according to the tariff agreed upon.

Such partial receptions, however, will only become definitive after the general reception of the whole of the railway.

30. After the entire completion of the works, the Company will execute, at their own expense, a complete official survey and plan of all the railway properties for public registration.

The Company will also, at their own expense, and conjointly with the Government, make a descriptive return of all bridges, aqueducts, and other works of art, constructed in conformity with the present *Cahier des charges;* an authentic copy of the official proceedings relative to the survey and plan, and of the descriptive return as to the works, will be deposited in the archives of the Ministry for Public Works.

31. Monuments already discovered, or that may become so, through the construction of railway works, shall in no way be damaged by the Company, who shall give information to the Government of the discovery of any such monuments, who will cause their removal, or take such other dispositions thereto as early as possible, in order not to obstruct the works.

Statues, medals, objects of art, or archæological fragments, &c., which may be discovered during the progress of the works, shall belong one half to the State, the other half to the Company, with the right, however, reserved to the Government of purchasing the same.

32. In all propositions, discussions, or acts relative to the railway, no other measures will be made use of than the following:—

For lengths, surfaces, and cubes, the fundamental unit will be the archine, equal to ¾ of the French mètre (0·75) or $\frac{5}{2}$ of the English foot, of which the length is equal to (0^{m}·30479).

For measures of weight, the ocque will be taken as the unit, which is to be considered equal to $\frac{5}{4}$ of the French kilogramme ($1^{k}\cdot25$) or $\frac{8}{3}$ of the English pound ($0^{k}\cdot4534$).

II. *Maintenance and Working.*

33. The railway and all its dependencies will be maintained in good repair, so that the traffic may be readily and securely carried on along the entire length.

The expenses of maintenance and repair, either ordinary or special, shall be supported entirely by the Company.

If, when once completed, the railway is not maintained in good repair, after due notice being served, the Minister for Public Works will provide for the same at the expense of the Company, and the expenses officially incurred will be recoverable on the presentation of regular accounts, which Government will render executory.

34. The locomotive-engines employed on the railway shall be constructed after the best models, as shall also be the passengers' carriages.

35. Government will take, conjointly with the Company, or at least after having given a hearing to the same, the necessary measures for the police, the security, the working and the maintenance of the railway, and of the works in connexion with it.

All expenses incurred in consequence of the execution of the measures prescribed by this regulation will be at the charge of Government.

36. The Company will submit to the approval of Government all by-laws it may consider requisite to make for the working of the railway.

37. The above regulations will be compulsory on the Concessionary Company, or for such as may hereafter obtain the necessary powers to construct branch lines or extensions in connexion with the railway which is the object of the present concession, and generally for all those who may introduce the construction of railways.

38. As regards everything relating to the maintenance and keeping in repair of the railway and its dependencies, the maintenance of the plant, and the working of the line, the Company will be subjected to the control and superintendence of the Administration.

III. *Continuance—Redemption—Forfeiture of the Concession—Caution-Money—Guarantee.*

39. The continuance of the Concession for the line of railway which is the object of the present *Cahier des charges*, or specification, shall be of ——, commencing from the date of the Firman of the Concession.

40. At the expiration of the period fixed for the Concession, and *ipso facto*, the Government will enter upon all the rights of the railway company, and will take possession of all the proceeds.

It will be the duty of the Company to have maintained the railway and all the works in good repair.

During the last five years preceding the expiration of the Concession, the Government will have the power to seize upon all the Company's revenues, and to employ the same in putting the railway and works in good repair, in case the Company should neglect to take measures to fulfil this obligation. As regards the plant, fuel, and stores, the Government shall be under the obligation of purchasing the same at a valuation; and reciprocally, if the Government requires it, the Company shall cede the same on those conditions.

The Government, however, shall only be obliged to purchase the stores requisite for six months' working.

41. At any period after the expiration of the first —— years of the Concession, the Government will have the power of redeeming the Concession for the railway.

To determine the price of redemption, the Company's net annual "proceeds" for the seven years immediately preceding that when the redemption is to be effected shall be taken; from these shall be deducted the two lowest annual proceeds, and an average will be taken of the five remaining years. This net average will constitute the value of the annuity which shall be paid to the Company for each of the remaining years which the Concession has to run.*

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* This course might entail great injustice on the Company; but the Turkish Government will be found so desirous of doing all that is right, that no fear of difficulty need arise in setting such a matter right in any Concession to be obtained. As a general rule, everything should go on rapidly improving in Turkish railways, unless some great mistakes are committed.

In no case shall the amount of the annuity be less than the net "proceeds" of the last of the seven years taken for the purpose of comparison.

The Company would besides receive, in the course of the three months after redemption, the repayments to which it would be entitled at the expiration of the Concession, according to Article 40.

In the event, however, of the Government having required the laying down of a second line of rails, the delay of —— years, at the expiration of which it would be entitled to effect the redemption, shall date from the time when such second line shall have been delivered over to public use.

42. If, within the lapse of one year from the date of the approbation of the general "itinerary," the Company has not commenced the works, then, *ipso facto*, all the rights of the present Concession will be thereby forfeited, without any notice or further proceedings whatever.

In the case of forfeiture, the sum deposited as caution-money will become the property of the Government.

43. In default of the Company having executed and completed the works within the period fixed by Article 1, or in default of the Company's fulfilment of the various obligations in the present *Cahier des charges*, the Company will incur forfeiture.

Steps will be taken for the continuation and completion of the works, as also for the due execution of the other engagements contracted by the Company, under an adjudication appointed under the present *Cahier des charges*, and for a valuation of the works constructed, materials in store, lands purchased, and of the portion of the railway already handed over for public use.

The same will be adjudged to the highest bidder for the materials and other matters included in the valuation.

The tenders may even be below the valuation. The ejected Company will receive from the new Company the value determined in this manner by the new tender. Should the said adjudication lead to no result, a second adjudication will be attempted after a lapse of six months; and should such a second attempt prove equally fruitless, then the Company will have definitively forfeited all their rights under the Concession and those portions of the railway then executed or delivered, will become the property of the State.

The portion of caution-money not yet returned will remain in the hands of the Government.

44. Should the working of the railway become interrupted, entirely or in part, through the fault of the Company, Government will, at the Company's expense and on the Company's responsibility, adopt the necessary measures to secure the provisional working of the line.

If, during the three months of the organization for such provisional service, the Company has not validly proved that it is in condition to continue the working, and if it is not so continued, forfeiture may be declared by the Government. On such declaration of forfeiture, the railway and its dependencies will be submitted to adjudication, and recourse will be had to the measures mentioned in the preceding Article.

45. The three preceding Articles will not apply, under circumstances where delay or cessation of the works or of the traffic arises from circumstances beyond the control of the Company, and of which satisfactory proof must be submitted to Government.

46. Before obtaining the Firman of Concession, the Company will deposit in the hands of Government, as provisional caution-money, the sum of ——, in cash or in Turkish stock, acceptable at the public Treasury.

Within the three months after the granting of the Firman of Concession, the provisional caution-money will be increased by the deposit of ——, which will thus constitute the definitive security from the Company.

47. From the date of the Concession, the sum first deposited becomes definitively part of the security, and interest at the rate of — per annum will be paid upon it to the Company; and the same with regard to the additional sum of caution-money from the date of its effective deposit.

48. The caution-money thus stipulated for in the preceding Article shall be returned to the Company in tenth parts, as the works proceed to completion; and in such manner that when it shall have carried out the works to the amount of ——, the Company will receive ——, and so on until the entire caution-money has been returned.

49. Government will determine on a form according to which the Company will make the return as to the amount of receipts and expenditure, and define the powers of supervision to be exercised by the Commissary over the acts of the Company.

We will now pass over some matters in the *Cahier des charges* which do not refer particularly to the subject of these pages, or which will be found in the Concession given hereafter.

76. During the term of the Concession, the property and revenue of the railway will be exempt of all tax; and the Company will be free of all stamp or other duties for all deeds relative to the Concession or the Company's organization.

82. The Company will have the power, under special authorization from the Government and subject to the laws and regulations of the country:—

1. To acquire lands, and to work them as plantations, or for cultivation or by means of buildings, &c.
2. To establish, under conditions to be determined by Government, common or other roads, iron or timber tramways, canals, docks, harbours, and shall be at liberty to work the same as means of communication between stations and the surrounding country.
3. To establish and to work any undertakings for transit on navigable rivers or by sea; or to make agreements with any establishments of the kind already existing or to be formed hereafter.
4. To undertake the working of mines, forests, quarries, or other similar industries.

CHAPTER V.

ARTICLES OF AGREEMENT FOR THE CONCESSION OF THE RAILWAY FROM SMYRNA TO AIDIN, ASIA MINOR.

ARTICLES of Agreement relative to the Railway from Smyrna to Guzel Hissar Aïdin, the year of the Hegira 1272, the 23rd Mouharrem, corresponding to the year 1856, the 23rd September: Between their Excellencies the Minister for Foreign Affairs, the Minister of Finances, and the Minister of Commerce and Public Works, for the Government of His Imperial Majesty the Sultan, of the one part; and Mr. Robert Wilkin, the representative of Sir Joseph Paxton and Messrs. George Wythes, William Jackson, and Augustus William Rixon, the founders of the Company, specially authorized under due power of Attorney, dated the 11th July, 1856, and acting under the full powers conferred on him for the purposes of the Railway, duly deposited at the Imperial Ministry of Finances, of the other part.

It has been agreed as follows:—

ART. 1.

The Government of His Imperial Majesty the Sultan concedes to the above-mentioned Company the line between Smyrna and Guzel Hissar Aïdin, on the under-mentioned conditions.

ART. 2.

This line commencing at Smyrna will terminate at Guzel Hissar Aïdin, traversing the plains or the environs of Seydi-Keuy, Oglanes, Trianda, Tourbalu, Baindir, Tireh, and thence by the passes of the chain of mountains of Gumé-Dagh, which will offer the greatest facilities to reach the terminus of Guzel Hissar Aïdin.

The Company engages to submit for the approbation of the Imperial Government, the detailed plan of the line, showing the two termini, within a period of eight months from the signing of the present Agreement, and earlier if possible.

The approximate estimate of the works of the line shall be submitted to the Imperial Government within eight months, at latest, from the date of these presents.

ART. 3.

The Company will have the power of establishing branch railways, or common roads in communication with the main line, within the limits of ten leagues, or thirty English miles, seventy thousand four hundred Turkish pics on either side of the main line. Any branch railroad will be deemed part of the main line; but on common roads made by the Company on lands conceded by the Government or by the inhabitants, no tolls shall be demanded. With the consent of Government, the Company will take a moderate toll on common paved roads, where the lands shall have been purchased by the Company, and which will form a part of the general Concession. The descriptive and detailed plan of these branch lines, ordinary paved roads, or common roads, will be previously submitted for the sanction of the Imperial Government.

ART. 4.

The Company will construct the works for a single line of rail, with the engagement to lay down a second line along the whole length of the railway, excepting through the tunnel under the mountain chain of Gumé-Dagh, as soon as the traffic increases, and as soon as the necessity for a double line of rails becomes evident by the increased circulation and the insufficiency of a single line.

ART. 5.

The Company will have power to erect at the termini of the line, at Smyrna and at Guzel Hissar Aïdin, as also at the different stations, such constructions as will be requisite for the working of and to facilitate the traffic on the railway. The Company will also have power to construct at the terminus of the line, at Smyrna, a special quay, with its dependencies for loading and unloading exclusively such goods as are to be carried on the line, and within the requisite limits for the working of the same. The Government will appoint Custom-house officers at the station or quay of the railway at Smyrna, and wheresoever else deemed necessary, to examine the goods carried by the Company, and to receive the Customs duties due thereon, without the consignees of such goods being subjected afterwards to any Custom-house formalities. The Company on their part undertake to construct at their own cost special offices for the use of these Custom-house officers, and to reserve offices or separate rooms for the Commissaries and other requisite *employés* of Government at the most important stations on the line.

ART. 6.

The Company will fence in the whole of the railway by hedges or palisades, and will maintain the whole of the railway and all its branches in complete working repair.

ART. 7.

The Company accept the obligation of constructing, at their own cost and on their own responsibility, the whole of the works of the railway, and of the branch lines hereinbefore conceded, so that the principal line may be worked and the traffic carried on throughout, at the expiration of four years from the date of the Firman of the Concession.

ART. 8.

At the crossing of all public roads and watercourses, the railway will be carried over or under such roads and watercourses by means of bridges or by making excavations. Level-crossings will only be allowed for roads of minor importance. The Company will abstain in all cases from destroying buildings devoted to public worship.

ART. 9.

The Company will establish telegraphic wires, placed immediately within the whole length of the railway, and on all the branch railroads. These telegraphic wires will be brought into operation simultaneously with the complete opening of the railway. The Company, however, will be subjected to a special regulation to be hereafter made relative to telegraphic correspondence, other than the communications referring to service of the railway. Under any circumstances, the Company shall place one of the telegraphic wires at the disposal of the Government and its Agents.

Art. 10.

All lands, being the property of the State, requisite for the principal line of railway or its branches, or for stations, storehouses, or offices, will be granted free to the Company.

Art. 11.

The lands required, being private property, will be purchased and paid for by the Concessionary Company, in conformity with the law of expropriation relative to the purchase of lands required for public works. In addition to the value of lands, all buildings, trees, and other matters therein, will be estimated and paid for. When the line shall have been set out, the Imperial Government will despatch commissaries and engineers, in order to place the Company in free possession of the lands belonging to the State, and at the same time to superintend the purchase by the Company, in conformity with the law of expropriation, of the private properties within the limits of the line of railway; a Commission will be appointed on the spot by the Government, in which the Company will be represented for the protection of its own interests.

The decision of this Commission will be immediately carried into effect by the Governor-General of the Province.

Art. 12.

Under the conditions hereinafter recited, the Imperial Government grants the Company all coal-mines situate on lands being the property of the State, which are not in the possession of any private individual, and within a distance of thirty English miles, or three hours' journey,* or seventy thousand four hundred Turkish pics, from either side of the line.

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* A Turkish mode of estimating distances.

If the coal-mines are not situate on State property, but on lands belonging to private individuals, a Commission, consisting of Government functionaries and two surveyors, will be appointed to estimate the value of such above-mentioned lands, and all existing dependencies. The value estimated by this Commission will be paid by the Concessionary Company, who, however, will be represented in the Commission.

Any private owner not agreeing to these conditions, will receive the proposal of working the mine himself, in conformity, however, with the Government established regulations thereunto; and for this purpose the extreme limit of two years will be appointed. If within such period, such coal-mine is not worked by the owner thereof, the lands where such coal-mines are situate will be taken out of the hands of the owners on the conditions above mentioned, and will be given to the Concessionary Company, to be by them worked on the conditions above recited.

The Concessionary Company will pay tithe in cash or in kind, at the option of Government, on the coal extracted at the Company's expense for the working of the railway. If the tithe is paid in kind, it will be consigned by the Company at Smyrna, and if in cash it will be estimated according to the market value of the commodity at the said town.

In addition to the tithe the Company will pay an extra charge of twelve per cent. on all coal other than that required for the purposes of the railway, which shall have been extracted from the mines conceded, whether such coal be sold in the interior or exterior, or whether made use of by the Company for purposes independent of the railway; the additional charge will be estimated on the sale price, and paid on delivery. All coal on which such charge shall have been paid will be free of Customs duty. At the expiration of fifty years from the date of the Concession, such mines, with all implements, tools, materials, coal, roadways leading to the mines, &c., will become the absolute property of the Government, free of charge.

The working of such coal-mines requiring a separate capital from that of one million two hundred thousand pounds sterling guaranteed for the railway, a separate account of expenditure and receipts will be kept thereof, and the loss or profit will be at the charge or advantage of the Company exclusively.

If within the period of two years from the date of the complete opening of the railway, the Company shall not have commenced the working of the above-mentioned mines, or of those already discovered, the Government will be at liberty to work them, or to grant them to another Company.

Art. 13.

The Company has the power to obtain, at their own expense, timber from State forests for the construction of the railway and its dependencies exclusively, and to obtain in the same manner from the quarries belonging to the State, all stone requisite for the railway works within thirty English miles, or seventy thousand four hundred Turkish pics on either side of the line, but under the obligation of conforming, in both cases, to the laws established thereunto.

As regards timber from forests, or stone from quarries, being private properties, the Company shall, previously to procuring the same, obtain the consent of the owners.

Art. 14.

Due returns and accounts of the cost of the works of the railway and its branch lines shall be made, and a special mode of estimating shall be established; and in conformity therewith, the accounts, signed and legalized, of the expenditure made on the works of the railway and its dependencies, shall be deposited with the Government, by whom, after examination, it will be placed in the archives. A special regulation will determine the forms according to which all returns shall be made by the Company to the State, relative to the annual expenditure of working and maintaining the railway, and relative to the Company's receipts.

Art. 15.

The construction of the railway works will be superintended by one or two Special Commissaries of the Imperial Government, who, in conformity with the instructions delivered to them, will attend to the proper construction of all the works of the railway, in order that they may be able to report that the works have been conducted in such perfect manner as to ensure the satisfactory working of the line. The salaries of these Commissaries will be paid by the Government, but all the necessary contingent expenses resulting from their mission will be defrayed by the Company.

Art. 16.

The Company will deposit with the Imperial Minister of Finance, in cash or in Turkish stock, the sum of twenty-four thousand pounds sterling, being two per cent. on the capital of one million two hundred thousand pounds sterling, as caution-money for the execution of all the clauses contained in the present Agreement. In case of its non-fulfilment of the required conditions, these twenty-four thousand pounds sterling will become the property of the public Treasury. If the works of the line are suspended or abandoned by the Company on whatever grounds, save any such as may be beyond their control, the Government will have the power to seize upon the line, whatever may be its condition, including all the materials, the Government granting the Company, however, six months, from the day of suspension or abandonment of the works, and giving the Company's agents notice of the same. If within this interval the Company does not recommence the works, the Government will take possession of the railway, and of all the materials and plant, and will confiscate the caution-money without the Company having the right to demand any indemnification on the grounds of expenditure or other matters whatsoever. Should, however, any unforeseen difficulties occur in making the tunnel, the Government will prolong the period appointed for the completion of the works. This prolongation will not extend beyond the exact period technically defined by the Special Commissary appointed by the Government, on the report of engineers appointed by the State and the Company.

Art. 17.

The railway will be designated by the title of "Ottoman Railway, from Smyrna to Aïdin, of His Imperial Majesty the Sultan," and will be placed under the special protection of the Sublime Porte, in order that the principles of the Concession and the general laws of the Empire may be observed and respected.

Art. 18.

The term of the Concession of the principal railway, as well as of its branches, which form the subject of Art. 3, will be for fifty years from the time appointed for the completion of the line. The Government of His Imperial Majesty the Sultan will have the power to renew the term of the concession, or to take possession of the railway in conformity with Article 19. If the Imperial Government renews the Concession at the expiration of the first term, the second Concession will be for twenty-five years. And at the expiration of the seventy-five years, the Sublime Porte will have the power to renew every twenty years; and the Concessionary Company will be under the obligation to accept of such renewal. In case of the taking possession of the line, or of the renewal of the Concession, the Company will receive official notice of the same two years before the expiration of the Concession. These conditions of the prolongation of the Concession, do not refer to the coal-mines and their dependencies.

Art. 19.

In the case of the Imperial Government resorting to the power herein reserved, of taking possession of the railway and its dependencies at the expiration of the concession, there will be paid to the Company the sum of one million pounds sterling, whatever may be the amount beyond one million which may have been expended for the establishment of the principal railway and the branches, provided that the net revenue of the undertaking does not exceed the sum of fifty thousand pounds sterling per annum, in which sum the profits arising from the coal-mines will not be included. If the actual expenditure on the works of the principal railway and its branches is less than one million, the Government will then only be called upon to pay the above-mentioned sum less than one million, even if the actual revenue of the Company exceeds the fifty thousand pounds sterling. The Government will pay the Company a sum of two hundred thousand pounds sterling for every ten thousand pounds sterling of nett annual revenue which the railway shall produce beyond the fifty thousand pounds sterling, and so on in proportion up to one hundred thousand pounds sterling, which will thus furnish a maximum of two millions sterling as the price of redemption; that is to say, that the Government will only pay two millions sterling as a maximum, whatever may be the nett revenue arising from the railway in excess of the one hundred thousand pounds sterling per annum. At the end of the second Concession, or of any renewals which the Government has the power to grant, the Sublime Porte will only pay one million two hundred thousand pounds sterling, whatever may be the importance of the revenues arising from the railway. At the end of the second Concession, or of any renewals, the Government will only recognise as capital expended on the works of the line, the above-mentioned sum of one million two hundred thousand pounds sterling.

If, however, the amount of capital has not actually attained the last-mentioned sum, then the Government will only be called upon to refund in proportion, according to the lesser sum expended, on the taking possession of the railway at the expiration of the Concession, and will only pay as a maximum the sum of one million two hundred thousand pounds sterling, whatever may be the sum in excess of such an amount of capital. The Government, however, will have the power of reimbursing the above-mentioned sum, as the price of taking possession of the railway, in Treasury Bonds (Sehim) bearing six per cent. interest per annum. In the latter case the revenues of the railway will remain as supplementary guarantee of the said Bonds.

Art. 20.

The State guarantees to the Company, during the Concession for fifty years, interest at the rate of six per cent. per annum on the maximum capital, to the extent of one million two hundred thousand pounds, expended on the construction of the works of the railway and its branches. If the capital expended is less than one million two hundred thousand pounds sterling, the State will only pay interest in proportion, and will not acknowledge any sum in excess of the one million two hundred thousand pounds sterling; and consequently, the annual interest guaranteed by the State will never exceed the sum of seventy thousand pounds sterling. Before the completion of the railway works to Guzel Hissar Aïdin, the guarantee of six per cent. will be due on the sums expended for the execution of the sections of line definitively opened for traffic, and in proportion to the expenses incurred for the construction of each section handed över, and which shall have been duly verified, and of which an account will be kept, both by the Company and by the Commissary appointed by Government. These accounts will be re-examined and regulated on the opening of the whole of the line from Smyrna to Guzel Hissar Aïdin, from which period the guarantee of six per cent. will be due on the whole of the railway. When the net profits of the line shall exceed seven per cent. on the capital guaranteed by the State, this excess, in whatever year it may be produced, and whatever may be its amount, will be equally divided between the Company and the Government. The half of such excess in the nett profits due to Government will be paid in cash by the Company at the Imperial Treasury. If the Government renews the Concession at the expiration of the first fifty years, in accordance with the terms defined in Art. 18, the guarantee of six per cent. shall entirely cease for the renewed Concessions; but the condition of paying to Government the one-half of profits in excess of the seven per cent., as well as all the other clauses of the Concession, will be maintained.

Art. 21.

If, contrary to every expectation, the Government should ever be under the necessity to pay, either entirely or in part, the interest of six per cent. which it guarantees on one million two hundred thousand pounds sterling, the Company undertakes to keep an exact account of all the sums thus paid by the State; and the nett revenues of the railway in excess of the six per cent. on the capital guaranteed by the State, in whatever year these may arise, shall, without any reference to the question of division between the State and the Company, be devoted to the payment of the sums which shall thus have been paid from the Imperial Treasury in consequence of the guaranteed interest on the line.

Art. 22.

The Government accepts the obligation of not granting any Concession for any other iron-road between Smyrna and Guzel Hissar Aïdin, which might compete, either directly with the line from Smyrna to Aïdin, or indirectly on the territories of this line, or by any indirect route taken in the environs between Smyrna and Guzel Hissar Aïdin, without having previously obtained the assent of the Company. The Company, on their side, engage not to extend the railway or the branch lines authorized beyond the limits determined by the present Agreement, without having previously obtained the consent of the Government.

Art. 23.

The whole of the establishments mentioned in the preceding Articles, such as the main line of railway, high-roads or ordinary roads paved, or secondary railroads, special quay, storehouses, stations, waggons, locomotives, machinery, and materials or constructions of all kinds, for the use of the railway, will return to the State, at the expiration of the Concession, in conformity with Art. 19. The whole of the objects above mentioned, and forming part of the railway and its dependencies, will be delivered in good repair and perfect working order.

Art. 24.

The Company is authorized to raise the capital requisite for the construction of the works of the railway and branches, by the issue of shares. The Company undertakes to reserve one-fourth of the said shares to be issued amongst the subjects of the Sublime Porte, at the same price and on the same conditions as to other shareholders. Any portion of such shares not taken up within a period fixed by the Company will be returned to them.

Art. 25.

Before commencing the working of the line, and within as short a delay as possible, the Company will define its statutes, determine on the general tariff, establish special regulations for the protection of its interests, the security of the lives and properties of passengers, the preservation of goods along the whole length of the line, and the details of its executive administration. The statutes, general tariff, and special regulations will be drawn up in the usual manner, submitted to the assent and approval of the Imperial Government, and put into execution after having received the sanction of his Imperial Majesty the Sultan. No increase or decrease will be made in the tariff without the consent of the Imperial Government. It is, however, to be understood, that the Government will not in any way interfere in the nomination of the staff of the Direction or of the *employés* on the line, or in anything whatever as to the regulations relating to the service and traffic agreed upon of the line. But the Company as a whole is subjected to the laws and general regulations of the Empire as established now or hereafter, in the same manner as persons in the service of the Company are individually under the protection of the nation to whom they belong; and all criminal or civil procedures brought against them will be maintained in the manner as heretofore.

Art. 26.

Any matter of difference that may arise between the Government and the Company, or the Company and the Government, will be tried and decided by a mixed Commission composed of arbitrators named in equal numbers by both sides. The decision of these arbitrators will be without appeal, and the forms according to which these arbitrators will be appointed, as also the umpire in the case of an equal division of votes, will be determined in the regulations of the interior administration of the railway, depending on the sanction of the Sublime Porte.

Art. 27.

The Company has the power of importing, duty free, all materials requisite for the construction and use of the railway and its dependencies exclusively, it being understood that preference is to be given to Turkish produce. If the Company imports materials beyond what is reasonably requisite for the use of the railway, these materials may be seized as contraband, and will fall within the regulations of Custom-house laws.

Art. 28.

The Company undertakes to transmit free of charge all State despatches, whether by telegraph or by train; and also to carry Government mails of prepaid letters at a slight charge, to be determined upon by a mixed Commission; gold and silver specie belonging to the Imperial Treasury at the rate of one-half of the general tariff; the military at one-third of the third class tariff, and war materials at one-third of the tariff of third class goods. The Company will reserve in the railway train, once, or twice if requisite, daily, a compartment sufficient for the Imperial mails, and a suitable place for the Post-office Agent.

Art. 29.

The statutes of the Company will be submitted to the approval and sanction of the Imperial Government within one year, at farthest, from the date of the Firman of Concession. The railway works having to be commenced within the same period of one year from the date of these presents, if the statutes of the Company are not submitted and the works commenced within such periods, the present Agreement will be considered as of non-effect, and the Company as having lost all their rights, and the caution-money confiscated.

Note.—The reader will not fail to observe that, throughout the above Concession, allusion is made most explicitly to the subject of lateral communications, of various kinds, on each side of the line of railway; nothing can be more intelligible than the terms in which these wants are expressed. It is a well-established fact, that in countries which have not obtained a state of high civilization, and which are not thickly populated, no traffic capable of affording a remunerative revenue will be obtained on railways deficient in lateral communications. If a line is made from a large inland town situate in a rich cultivated district down to the coast, most indubitably there will be a large traffic, *so far* as the inland town is capable of supplying it; and it will be found that the environs of such town will improve very rapidly after the opening of the railway, which will cause a great increase of cultivation. But towns some distance off the line will remain unaffected, until the advantages of railway communication are brought to them by means of branches or roads, which should be made sufficient for the purposes required, and no more; then cultivation will extend also around such towns, and thus railways will cause a great change on the face of the country.

CHAPTER VI.

FORM OF CONTRACT FOR A FOREIGN LINE OF RAILWAY, AND SPECIFICATION.

ARTICLES of Contract made the —— day of ——, A.D. ——, between —— ——, of —— ——, Contractor for Public Works of the first part; and the Company formed under the authority of His Imperial Majesty THE SULTAN, and designated by the name of "*The Ottoman Railway from —— to —— of His Imperial Majesty the Sultan*," and hereinafter called the Company, of the second part:

Whereas the Government of His Imperial Majesty the Sultan has conceded to the Company the line of railway from —— to —— on the conditions expressed in Articles — to —, both inclusive, of an Agreement made the —— day of ——, ——, between the Turkish Ministers of Foreign Affairs, of Finance, and of Commerce and Public Works, representing the Turkish Government, of the one part, and —— ——, representing the Founders of the Company, of the other part, and additional articles (if any); and the Concession has been confirmed by an Imperial Firman. And Whereas, in accordance with Article — of the Agreement for the Concession, the Statutes of the Company have been duly submitted to the Turkish Government for their approbation and sanction, and such approbation and sanction have been obtained (*or* are expected to be obtained, *as the case may be*). But at present arrangements have not been perfected for the complete establishment of the Company, and only part of the shares of the Company's capital have been taken up. And Whereas, in conformity with the Agreement for the Concession, six per cent. Bonds of the —— Government (*as the case may be*) to the amount of —— have been duly deposited on behalf of the Company with ——, at ——, and remain there deposited. And Whereas, in accordance with Art. — of the above-named Agreement for the Concession, the works of the railway have been duly commenced. And Whereas —— —— has tendered for the execution of the railway, and his tender has been accepted by (the Directors, *or* Provisional Directors, *as the case may be*): And whereas heads of arrangement for carrying out his contract were provisionally entered into on the —— day of ——, between —— —— and —— —— (*the said Contractor*): And whereas it has been agreed between the Company and the said —— —— that these presents shall be entered into by way of Contract for the execution of the railway: And whereas it was one of the heads of the agreement provisionally entered into, that the said —— —— should find sureties, to be approved by the Directors of the Company, to the amount of ——, for the due performance of the Contract; and the said —— —— has proposed —— and —— as his sureties accordingly, and they have been approved by the Directors of the Company: it has been agreed that they shall be the sureties accordingly, and shall, with the said —— ——, enter into a Deed of Covenant or Survivorship, for the due performance of this Contract.

Now, therefore, these presents witness that the said —— ——, so far as relates to such part of this Contract as is to be fulfilled by him, doth hereby, for himself, his heirs, executors, and administrators, covenant with the Company, and the Company, so far as relates to such part of this Contract as is to be fulfilled by them, do hereby for themselves covenant with the said —— ——, his executors and administrators, as follows (that is to say):—

The Schedule to these presents shall be deemed part of them.

The expression "the Contractor" mentioned in these presents and in the schedule shall mean the said ——

The Company have appointed —— —— to be the Company's Engineer-in-chief in Turkey, and —— —— to be the Company's Consulting Engineer in England, for the purposes of this Contract. On either of them, or any successor of either of them, ceasing to be the Company's Engineer, the Company will appoint another English Civil Engineer to be the Company's Engineer in his place, and will give to the Contractor notice in writing of every such cessor and appointment.

The expression "the Company's Engineer," wherever occurring in these presents or in the Schedule to these presents, shall apply to and mean either of the Company's engineers.

The expression "the Government," when occurring in these presents or in the Schedule, shall mean the Turkish Government.

The Contractor and the Company respectively will perform and observe for the purposes of this Contract all the terms and conditions expressed in the said Schedule.

The Contractor will duly acquire in the name of the Company, and according to the laws of the Ottoman Empire, and in conformity with the Articles 10 and 11 of the Concession, all the land necessary for the railway stations, sidings, and all the works from —— to ——, and at those two places respectively. The Contractor will procure the due and complete conveyance to the Company of all the land acquired (excepting always such as he may acquire for temporary purposes); and the documents relating to the lands shall be delivered to the Company (at least —— months) before the time fixed by these presents for the completion of the railway.

Before the commencement of any works on any portions of the lands, the Contractor shall complete the fencing thereof whenever he is directed to do so by the Company's Engineer; and as soon as any portions of land are so fenced in near large towns, he shall put on guards to prevent trespassers coming on to any part of the line so fenced in. The Contractor shall otherwise take such legal measures as shall secure the privacy of the works from all trespass. In taking such measures he shall receive all the assistance that the Company may be able to give him under the Concession.*

The Company's Engineer will set out the widths of the lands to be acquired and conveyed to the Company, and which lands shall be sufficient for a double line of way throughout, with such additions as the Engineer may deem necessary for any of the dependencies of the railway or works.

Before commencing any works, the Contractor shall use his best endeavours to the satisfaction of the Company's Engineer for completing the purchase of any of the lands to be acquired, more particularly for works shortly to be commenced; and he shall be responsible and hold the Company indemnified from any consequences that may arise from trespass or otherwise.

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* In the vicinity of large towns it will be found, unless such measures be adopted, that the works will become the public promenade, to the danger of the inhabitants themselves, and much to the annoyance of the Contractor, as well as the Company. If adopted at once and from the commencement, such a course will give no offence; but after a time the public consider they have acquired a right, and any attempt to obstruct their free passage will occasion great confusion.

The railway shall be made as a railway of the first class with a single line of rails, except only at all the stations, and more particularly at the terminal stations, where there shall be provided all the accommodation which the Company's Engineer may direct, and the other works shall be made suitable to a first-class railway. The railway and works shall be constructed and carried on under the sole control of the Company's Engineer.

The railway and works shall be made and carried on according to the Specification, general conditions and Schedule, and in conformity with the —— drawings hereunto annexed, and which drawings are only to be considered as specimens or types of the style or character of construction as far and for such works as the drawings describe.* Special drawings for all the works will be supplied by the Company's Engineer during the course of construction, which will be as nearly as possible in conformity with the specimen drawings, but with such modifications and alterations as the Company's Engineer may deem requisite, and of which he shall be the sole judge.

The Company's Engineer will set out the line in the direction which he considers the most advantageous to the Company, and will determine the situation of the various works; and the Contractor hereby agrees to accept of such line of direction, and of the section, or otherwise of the Company's Engineer's determinations without offering any objection thereto. He may, however, if he deems it advisable, offer any suggestion to the Board of Directors on the subject; but he hereby agrees to accept of their decision as final, and without appeal to any one whatsoever.

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* When a complete set of working drawings of the works is not added to the contract for European works, a set of specimen drawings at least is always annexed. This is not always done for foreign lines; and from the writer's experience, he believes such omission to be a great, serious, and dangerous mistake. The absence of drawings is generally occasioned either because no complete working section is prepared, or through great haste to conclude the Contract. Such omission is certain to lead to great differences of opinion during construction, as to the style of construction of even the most ordinary works, and is therefore a dangerous course to pursue. A few days only are required to produce a set of specimen drawings, when sufficient hands are set on to the work, and must necessarily lead to a much clearer understanding of the kind of works that will be required than mere description can do. There can afterwards be no disputes as to the style of bridges, viaducts, culverts, permanent way fencing, level crossings, general character of lodges and general stations and buildings, &c. As to any special buildings or bridges or works to be constructed, such specimen drawings are still more indispensable on foreign works than in Europe.

The details of works, whether they be line works, station or other buildings, or special works, to be executed under the Contract and Schedule, as far as the same are not expressed in these presents, or in the Schedule, or in the specimen drawings annexed thereto, will be determined by the Company's Engineer in Turkey. Should, however, any question arise thereon between the Company or the Company's Engineer in Turkey on the one hand, and the Contractor on the other hand, it shall be referred to and fully determined by the Company's Engineer in England, and his decision shall be accepted by both parties, and shall be without appeal; but it is to be understood most distinctly as regards workmanship, materials, and style of construction, that all the works are to be executed as for a railway of the first class, and that they are to be in every respect sufficient for the traffic which the Company is entitled to anticipate under the Concession.

The works shall be made in conformity with any modifications or additions, if any, that may be required, to be in accordance with the provisions of the Agreement for the Concession, as the Company's Engineer from time to time thinks requisite.

[*The following Article will have to be introduced only in the event of the works having been commenced previous to the Contract being made.*]

The Contractor will repay the whole amount expended on commencement and partial execution of the works of the railway, or in relation thereto, from the —— to the day on which the Contractor takes the works in hand; and in consideration thereof, all the plant and machinery, buildings and materials, which have been provided, shall become the property of the Contractor, and shall be deemed works done and materials provided under and according to this Contract.

Should any modifications of, or additions to, the terms of the Concession be required by the Turkish Government, the consent of the Company thereto shall not be given without the previous consent, in writing, of the Contractor; but in the event of any modification or addition being made by the Government, the Contractor shall be bound by every such modification and addition in the same manner as the Company.

The whole of the works must be completed within (*time of completion*) from the date of the Firman of the Concession, as provided by Article —— of Agreement for the Concession. The Contractor must at once undertake the works with sufficient plant and workmen and all requisites as above or hereinafter mentioned, and within two months from the date of these presents the works shall be in full progress, to the complete satisfaction of the Company's Engineer.

If any extension of the time mentioned in the above-said Article of the Agreement for the Concession should be found absolutely requisite, to the satisfaction of the Company, for the completion (of the work, *or* of any particular works*), the Company will, at the request, made in writing, of the Contractor, use all reasonable endeavours to obtain from Government such extension of time. Such extension of time being obtained, the Contractor shall complete the works within the extended time.

The railway shall be divided into the following sections.

[*Here a short descriptive summary of the lengths and situations of the different sections.*]

Every section shall be made, completed, and handed over to the Company, in thorough repair and good working condition, at latest by the time as under prescribed.

[*Here describe the time to be allowed for the completion and delivery of each section, having regard to the terms of the Concession as to extension of time, if any.*]

The Contractor will execute the whole of the railway and works, above, below, or on the levels, according to the section to be provided by the Company's Engineer, including the special (jetties, quays, docks, Custom-house warehouses, *as the case may be*, at ——), with all stations, sheds, buildings, with conveniences, appurtenances, and necessaries, for carrying on the traffic of passengers, goods, cattle, and all other matters, as soon as the railway is delivered over for public use, platforms, water-supply, signals, approaches, fences, electric telegraph, and other requisites and conveniences; and will provide and maintain all kinds of plant, machinery used on such works, scaffolding, centres, templates, tools and utensils, materials, and labour of every kind, that may be necessary for duly and efficiently executing and completing the works, and maintaining the same during their progress and until their completion and delivery, and the whole to the satisfaction of the Company's Engineer.

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* The expressions here must of course depend on the terms of the Concession.

The Contractor will provide, at an expenditure of (£——), all the plant, and all the rolling stock, and all the requisites of every kind, fixed and moveable, for the working of the railway and the carrying on of the traffic, according to the directions and instructions, and drawings if deemed necessary, to be supplied by the Company's Engineer, within a period of —— from the date of these presents.

[*Until the Engineer has had opportunities for making himself acquainted with the nature of the local details and peculiarities of the traffic, it will be found advisable not to hasten the delivery of plant and rolling stock. When he has become acquainted with these local features, he will be better able to describe and advise judiciously. Some light tank-engines will, in many instances, be found very useful, as also carriages adapted for the heat of summer. Smoking is constantly going on in the East, and the cloth cushions and linings of first-class carriages are soon seriously damaged. The character of the goods traffic requires attention; and a great number of horses are constantly being moved about the country.*]

All the plant and rolling stock in quantity and kind shall be proper for a railway of the first class, and shall be sufficient in every respect for the due and efficient reception, accommodation, working, and delivery of the traffic, and shall be delivered in the most complete and perfect condition, and to the satisfaction of the Company's Engineer. On every section being handed over to the Company, the plant and rolling stock requisite for working the same shall be handed over with it, to the satisfaction of the Company's Engineer.

The Contractor will indemnify the Provisional Directors of the Company and the Directors of the Company and the Company respectively, from all liabilities already and to be hereafter incurred, under the Agreement for the Concession and the Firman of Concession, down to the time when the Company's Engineer shall have certified the final completion of this Contract (*This is a clause which will have to be modified according to the circumstances of the case*).

The Company will pay to the Contractor for the complete fulfilment of his part of this Contract, whether with or without any modifications, extras, or additions, the sum of ——, by such instalments as the Company's Engineer from time to time certifies to be payable to the Contractor according to this Contract; and the amount to be from time to time so certified, shall as nearly as possible be so adjusted that the whole amount certified shall bear to the whole sum of (*the total contract sum*) the same proportion as the cost of the works then done and the Company's materials then provided shall bear to the cost of the whole work, and all materials for permanent way, plant, and rolling stock. For the purposes of such certificates, materials or plant shall be deemed to have been provided, on the production of the Bills of Lading and Policies of Insurance thereof, and as regards all other of the Company's materials as or when deposited on or near the site of the works. Every amount so certified to be paid as to one-half thereof in cash, and as to the other half thereof in fully paid-up shares of the Company, to be registered in the Contractor's name, excepting in as far as hereinafter provided. And the Company shall not, under any circumstances or on any account, be liable to pay to the Contractor a greater sum than (*the total contract amount*), or to pay the same, or any part thereof otherwise than is provided by these presents.

Provided always that all Certificates given during the progress of the works by the Company's Engineer shall be considered, not as final, but as given on account only, and shall always be subject to revision at any time previous to the completing of this Contract.

Provided, as regards every section, that the payments on the certificates of the Company's Engineer shall be made at the rate of ninety per cent. on the amount certified, as to one-half thereof in cash, and as to the other half thereof in fully paid-up shares. Of the ten per cent. retained, one-half shall be paid, one-half in cash and the other half in fully paid-up shares, when the Company's Engineer certifies that the section on which such amount is payable has been handed over complete, and in every respect in good repair and working order. The remaining five per cent. shall be paid, one-half in cash and one-half in fully paid-up shares, six months afterwards, when the Company's Engineer shall have certified that such section continues in satisfactory repair and working order. But before such final certificate shall become valid, and before the amount is payable thereon, the Contractor shall endorse the same as being a full and complete discharge of all claims arising under this Contract, as relating to such section.

Provided, as regards materials or plant certified for as above, on Bills of Lading and Policies of Insurance, that the Contractor shall be fully responsible for the same until they are delivered to the Company, at or near the site of the works at ——, according to the directions given in writing by the Company's Engineer. All materials thus delivered, in respect of which any advances shall have been made, are to be deemed and regarded as the Company's property.

The Company will take all measures requisite for the complete establishment of the Company; but the fulfilment of this Article shall not be a condition precedent to the fulfilment by the Contractor of his part of the Contract.

The Company will from time to time exercise their powers so as (consistently with the terms of this Contract) to afford to the Contractor all the facilities they may duly grant to the Contractor for the performance of his part of the Contract.

The Contractor will receive all the advantages that may be duly derived from the privileges conceded by the Government under the Concession, as regards the free grants of Government lands required for the works, as also the right of obtaining timber and stone free of cost from Government property within thirty English miles on each side of the line; but he shall, previously to doing so, ascertain by all satisfactory means that any such property is really Government land, and in all respects conform to the laws of the land in obtaining either the land, the timber, or the stone.

The Contractor shall be responsible for and hold the Company indemnified in every respect in regard to any acts committed, by mistake or otherwise, by any of his agents.

The Company will, from time to time, duly make calls on all the shares of their capital not fully paid up, and use all reasonable endeavours to enforce the payment of the calls, and will duly apply the amount from time to time received in respect of the shares, in or towards payment to the Contractor of the sums from time to time payable to him in cash, according to this Contract. Provided that if, by reason of failure or of the inability of the Company or its Directors to procure the due payment of calls, or from any other cause, default shall be made in certifying, or in payment of the amounts certified as aforesaid, the Contractor shall be at liberty, after one month's notice given to that effect, to suspend the execution of the works whilst such default shall continue; and if such default shall be continued for six calendar months, absolutely to determine this Contract as from that time, and in the first of such cases shall be entitled to a proportionate extension of time.

All questions arising between the Company or the Company's Engineer on the one hand, and the Contractor on the other hand, touching the construction, intent, effect, incidents, consequences, or fulfilment of this Contract, otherwise than as above mentioned, shall be referred to and determined by arbitration, and may at any time be so referred by the parties in difference, or by any of them, after not less than twenty-one days' notice, in writing, to the other or others of them.

—— ——, or him failing another English engineer, to be, from time to time, on the application of the parties in difference, or of any of them, after not less than twenty-one days' notice, in writing, to the other or others of them, named by the President of the Institution of Civil Engineers, shall be sole Arbitrator for the purposes of these presents.

The award of the Arbitrator, if made under his hand, and ready to be delivered to the parties in difference within thirty days after the reference is made to him, or within such further time, if any, as he shall from time to time appoint, by writing under his hand, shall be binding and conclusive on the parties in difference; and all such things shall forthwith be done, and omitted, and suffered, as by the award shall be required.

The Arbitrator may, if he shall think proper, make several awards, and every such award shall be binding and conclusive as to all matters to which it extends, and as if the matters awarded on were the whole matter required.

The Arbitrator shall have full power, at his discretion, to examine the books, accounts, and papers of the parties in difference respectively, relating to the matter referred, and to examine their respective officers, servants, and witnesses on oath, or affirmation, or statutory declaration in lieu of oath.

The Arbitrator may proceed in the reference as he shall think fit, and after notice to both parties in the absence of both or either of them.

The costs of the reference and arbitration, and of the award, shall be in the discretion of the arbitrator; and if he shall not otherwise award the costs of the arbitration and of the award, then the parties in difference shall bear their own costs.

The submission to reference, made by these presents, may at any time be made a rule of any Court of Law or Equity on the application of the parties in difference, or any of them, and the Court may remit the matter to the arbitrator with any directions the Court think fit.

Full effect shall be given under the Common Law Procedure Act, and every other Act from time to time in force applicable in that behalf, to the provisions of these presents touching arbitration.

In witness whereof the said —— hath hereunto set his hand and seal, and the said Company their common seal, the day and year first above written.

SCHEDULE.

SPECIFICATION AND GENERAL CONDITIONS.

This Specification of work refers to the making and completing the whole of the railway and works from —— to ——, in sections as mentioned above, and according to instructions herewith exhibited, or that may from time to time be furnished, and in conformity with drawings that shall be from time to time supplied by the Company's Engineer, concerning the following general list of works.

1. Fencing in on both sides of the line, and of the whole of the Company's property, or of any roads.
2. Excavations, embankments, and all earthworks; raising, lowering, diverting, or in any ways altering roads, metaling, and completing the same.
3. Bridges, viaducts, aqueducts, culverts, retaining and other walls.
4. Forming and levelling the railway, according to the working section to be hereafter supplied, and ballasting the same for a single line of railway.
5. Providing the whole of the permanent-way materials, ballast, and laying down of the whole complete.
6. Tunnel and contingent works.*
7. Wharf, jetties, and contingent works for supplying accommodation to shipping, including roads, paving, and metaling.
8. Warehouse and sheds.
9. Stations, engine-sheds and workshops, tanks, and all other works that may be required as above mentioned.

FENCING.

The fencing to consist of post-and-rail fencing, mound and quicks, (see drawing No. —), or of dwarf rubble walling (see same drawing),† or of wrought fencing (see drawing No. —).

The post-and-rail fencing to be of posts and four rails; the posts to be of sound larch not less than six feet long, four of which are to be above the surface of the ground, the smallest end at least 6 in. × 3 in., and the head of each post to be hooped with iron hooping 1 in. wide and overlapping at least 2 in., and well nailed to the post by six English inch-and-a-half nails. The posts not to be more than 10 ft. apart, well rammed and firmly fixed in the ground. Each post to have four mortice-holes for the reception of the rails, the first one being 6 in., the second 1 ft. 8 in., the third 2 ft. 8 in., and the lower one 3 ft. 4in. from the top of the posts; into these mortices the rails are to be properly scarf tenoned, so that the ends may come at least 3 in. through. The rails to be of sound larch, and straight, the upper one not less than 4 in. × 1½ in., and the others not less than 3 in. × 1½ in. A prick-post shall be driven in the middle of each length, and each rail is to be strongly nailed and clenched thereto. These prick-posts are to be of larch, not less than 5 ft. 6 in. long, and 8 square inches in section. Before setting up, all the timber is to be paid over with creosote.*

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* The tunnel referred to in the Concession was one of very great length: it never was, and, according to every probability, never will be made. Even short tunnels can only be attempted with great difficulties in Turkey, unless under very exceptional and favourable circumstances.

† The materials for fencing will be found to vary very widely, according to climate. In many places the Cactus will make a good fence; the wild Osage Orange will also make an effectual fence after a short time, but to be successful it must not be more than ten or twelve miles from the sea; the Briar and wild Vine, mixed, are also good fencing materials in many districts. It must, however, be noticed of these hot climates, that the same kind of quicks do not by any means succeed in every place; and the final determination upon this subject requires a little experience of the localities.

The fencing is to be placed in such line and situation as shall be set out by the Engineer, and executed in all respects to his satisfaction.

A quickset fence is to be formed within the posts and rails wherever directed, and shall be set in a double row, in manner to be hereafter determined by the Company's Engineer. A mound of good soil to receive the quicks shall, in every instance, be made from the soil excavated in forming the ditches, and, as shown in drawing ——. Ditches are to be cut along the whole of the fencing, as shall be directed by the Engineers, never less than 15 in. wide at bottom, 2 ft. deep, and otherwise as shown in drawing ——. Wherever greater breadth and depth are required to secure sufficient outfall, the ditch shall be excavated to such necessary dimensions. In every case where these side-ditches shall intersect any ditch or drain already existing, great care must be taken to effect a workmanlike communication, and to puddle securely between the ditches and the cuttings, so as to prevent any danger or injury to the slopes from water breaking through into the cuttings. In all cases thoroughly sufficient drainage must be secured.

All the fencing, including the quick, is to be maintained by the Contractor until the several sections are completed, and at such completion it is to be left, in every respect, in good condition, to the satisfaction of the Company's Engineer.

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* Unless this be done, the fencing will be pulled down for firewood.

The fence-walling shall consist of good bonded rubble masonry in mortar, well connected with all existing fences. The walls are to be properly footed, eighteen inches thick at the ground-line, and fourteen inches thick at the underside of the coping. The walls to be, in every case, four feet high above the level of the adjoining ground, exclusive of the coping, which is not to be less than one foot deep, and formed of stones set on edge in mortar. The mortar for these walls to be of the same quality and description as that hereinafter specified; the whole to the satisfaction of the Company's Engineer.

Where the Company's Engineer shall allow any fence-walls to be built of random rubble as blasted from the rocks, such random rubble shall be built in the manner hereafter specified for random rubble masonry.

FENCE-GATES.

Fence-gates are to be provided and fixed by the Contractor wherever required by the Engineer; they are to consist of good sound timber, wrought, framed, and put together in a workmanlike manner, with proper fastenings and wrought-iron hinges (see drawing No. —). The posts are to be firmly fixed in the ground to the depth shown, the ground well rammed, and the fencing is to be made good up to them. The whole to be made and fixed in a manner satisfactory to the Company's Engineer. Every gate is to be provided with a chain secured to it with some approved means of fastening.

GATES FOR LEVEL-CROSSINGS.

Wherever public roads are crossed on the level, proper gates are to be provided and erected on both sides of the railway.

All these gates are to be of the best Memel fir, of the form and dimensions shown on drawing No. —, truly framed, wrought fair on all the surfaces, and the arrises chamfered off, and the whole finished in a workmanlike manner. The hanging and other posts of these gates are to be set parallel to the centre line of the railway; they are to be stayed or braced at the depth below the surface of the ground shown on the drawing, and the whole is to be filled up with concrete in a manner satisfactory to the Company's Engineer.

All the gates are to be provided with shooting bolts and locks of approved description, and all ironwork shown on the drawing. The whole to receive four coats of the best oil-paint, of such colour as the Company's Engineer may direct.

The drawing shows a square crossing over the railway, but the Contractor will have to provide such additional clapping-posts as the Company's Engineer may consider necessary to suit each particular crossing, and all requisite return or other fencing.

EARTHWORKS.

The ground is to be thoroughly cleared of all encumbrances, and in every case where the embankments are to be less than five feet in height, the seat of such embankments shall have all roots of trees, or otherwise, carefully grubbed up and cleared away.

The width at formation-level, through all cuttings and embankments, shall be eighteen feet before the slopes are soiled.

In excavating the cuttings and forming the embankments, the Contractor must strictly adhere to the depths and heights figured on the longitudinal section, and form the slopes to such inclinations as the Company's Engineer shall direct.

The Contractor is to remove, and carefully put on one side, sufficient top-soil from the sites of the cuttings and embankments to soil the slopes when trimmed to a thickness of at least six inches, measured at right angles to the plane of the slope. In the event of his neglecting to so set aside sufficient top-soil, he will have to procure the deficiency at his own expense.

In carrying on the embankments they must, as the work proceeds, be formed at once to the full width, due allowance being made for settlement, and such a width at all times maintained that no additions to the sides of any embankments shall at any time become necessary to widen them to their full width.

Where, from any particular motive, it may become desirable to set aside this general rule of always forming the embankments to their full width, and where the embankments are from the beginning formed of a narrower width than eighteen feet, with the intention of widening them after by side-tipping, the slopes of such embankments shall always be trenched up to the satisfaction of the Company's Engineer, in trenches parallel to the centre line, before the side-tipping is commenced on any portion whatever of the slopes, and the side-tipping shall then be constantly continued until the embankment is brought to its full width and proper slope.*

In the forming of embankments, every care must be taken to make due allowance for the settlement of the earth, as should any embankment be formed of insufficient height, the deficiency will have to be made good by the Contractor with ballast procured at his own expense.

In side-lying ground, benchings will have to be cut along the seat of the embankment, and a toe excavated at the low-lying foot of the embankment, and every precaution taken, by drainage or otherwise, to secure its stability, as the Company's Engineer may direct and to his satisfaction.

Wherever the seat of the embankment consists of soft wet materials, the Contractor will cut trenches four feet wide along one or both sides under the foot or feet of the slopes, through the same down, to a solid foundation as the Company's Engineer may direct, wherever such solid foundation is not at an average greater depth than six feet below the surface of the ground, and fill in such trenches with hard dry material, and carry the same to a height of three feet above the surface of the ground and along the inside of the slope, and apply such measures of drainage or safety, as the Company's Engineer may deem necessary.

On no account shall any mud or slush, or other watery stuff, such as may be excavated from soaks or springs met with in cuttings, be allowed to be carried to form embankments; neither shall wet peat or other watery stuff from any side-cutting be used for any such purpose;

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* The forming of embankments to their full width at once, by tipping forward, and without the after use of side-waggons, is much more requisite in hot climates than in more temperate countries. The power of the sun is so great, that the slopes of embankments become completely baked, and so hard that earth tipped upon the sides afterwards has no adhesion, and the first heavy rains cause such materials to slip. Unless the damage is at once repaired, which is not always convenient, settlement of the permanent way soon ensues, more particularly under heavy rains. Without proper precautions such an embankment is a perpetual source of outlay.

but all the materials shall be dry and such as the Company's Engineer considers proper.

When the embankments have been sufficiently advanced, and when they have sufficiently settled, the slopes shall be properly and truly formed and trimmed to the required slopes, and covered with the vegetable earth laid aside for that purpose. And when the cuttings have been sufficiently advanced, and the slopes truly battered* to their proper inclination, these slopes also shall be carefully trimmed and soiled with the vegetable earth set aside for the purpose. Should any cracks appear in the sides of embankments, they shall be carefully punned up. At the same time that the slopes of cuttings are being trimmed, they shall also be truly and neatly bottomed out.

The tops of embankments shall also be truly dressed when the slopes are being trimmed and soiled.

In the event of any soaks or springs being met with in any of the slopes of cuttings, a sufficiency of dry rubble or other drains shall be laid down in such slopes, and such other measures taken as the Company's Engineer may direct, to prevent the earthworks from being in any way injured.

Wherever, by reason of a stream flowing by the foot of an embankment, or by reason of its being by any possibility flooded during the rainy season, or of any other such cause, the Company's Engineer deems it necessary, such foot of an embankment shall be pitched to such height and in such manner as he may direct. And in the event also of the Company's Engineer deeming it requisite, on account of soaks or springs, the Contractor shall pitch any portion of the slopes of cuttings as he may be directed to do by the Company's Engineer.

In rock-cuttings no trimming will be requisite, but the Contractor will remove any portions of the slopes which the Company's Engineer may consider loose, and underpin in a substantial manner any portions of the slopes which the Company's Engineer may deem unsafe. In all rock-excavations it will be strictly enjoined that all possible precautions be taken by the Contractor to ensure the safety of the men, and he will particularly attend to any instructions from the Company's Engineer to this intent.

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* The slope of an excavation that is not true and perfectly out of winding, is soon severely damaged by the heavy rains of a wet season in the East.

Side-drains shall be cut at the bottom of all cuttings, and embankments if required, of such dimensions as the Company's Engineer may deem necessary for ensuring a perfect system of drainage throughout the length of the line; and any of these side-drains shall be pitched wherever he gives directions for such work to be done.

The Contractor is to keep the cuttings free from water during the progress of the works, and will adopt all such measures as the Company's Engineer may deem requisite to effect this purpose.

By permission from the Company's Engineer, the Contractor may, if he deems it desirable, put so much of the excavation to spoil as he may wish to do; but in the event of any deficiency of earthworks arising in consequence, for forming embankments, such deficiency must be made up by the Contractor, from side-cutting or otherwise, as the Company's Engineer may direct.

In the above case relating to spoil-banks, or wherever the Company's Engineer may direct that any excavated earth shall be taken to spoil, the spoil-banks will be formed by the Contractor, wherever and in such manner, as regards the forming of the slopes, or the vegetable soil to be laid thereon, as the Company's Engineer shall direct.

The earth, or other material arising from excavations, is to be disposed of, as the Company's Engineer shall direct, in the embankments or approaches, or, in case of surplus, in spoil-banks

Wherever embankments are formed from side-cutting, obtained from excavating trenches or tanks by the side of the embankments, the edges of such tanks shall in no case be nearer than ten feet to the foot of the embankment by the side of which such tanks are excavated; and where of greater depth than three feet, the sides shall be battered throughout the length by the side of the embankment, to a slope of one and a half to one at the least; nor shall such tanks be carried nearer than five feet towards the fencing of the line. Where practicable, a ditch shall be cut from such tanks to the nearest watercourse, or other channel, by means of which water may be carried off.

In case the Company's Engineer shall determine to obtain any earth from other description of side-cutting than the above, the Contractor will execute such side-cutting, wherever directed, and in such form, and to such depth and extent, as shall be determined by the Company's Engineer, who will direct how earth so obtained is to be disposed of, in the same manner as he will give directions as to the disposal of any other earth arising from excavation.

In the forming of embankments from side-cutting, the Contractor will be careful that the earth be deposited in a solid mass to the full height of the embankment, allowing for shrinkage and settlement, and to the full width and batter of the slopes, and not by patches deposited about indiscriminately,

The above description of earthwork will equally apply to all cases of roads for bridge or field occupation approaches, or diversions of roads or streams, or any other purpose of a like character.

In all such matters everything shall be performed in a workmanlike manner, to the satisfaction of the Company's Engineer.

The Engineer will set out the work, and give the necessary levels from time to time as may be required; the Contractor to find him all requisite labour, chainmen, staffholders, poles, stumps, or other matters that he may require for these purposes, or for measuring up the work, as well as for the conveyance of his instruments, or other apparatus, from place to place as he may require.

In carrying embankments over any bridge or culvert to be covered thereby, care must be taken to adopt means, approved of by the Engineer, either by a temporary bridge, or staging, or other means, to have the embankment brought up equally on both sides of the bridge or culvert, so that the weight of the earth may be brought to bear equally over all parts thereof at the same time; and should any injury or derangement arise to any bridge or culvert, the Contractor will be required to rebuild it at his own expense, or make good the damage in any way satisfactory to the Company's Engineer.

The Contractor will be at liberty to make use of, and properly apply in the works, any materials—such as stone, gravel, clay, or sand—which the Company's Engineer may approve of; but any deficiency of material for any embankment, approaches, or otherwise, arising in consequence, shall be made good by the Contractor, either by side-cutting or by increasing the batter of the slopes of cuttings, or otherwise widening them, as the Company's Engineer may direct.

EXCAVATIONS FOR FOUNDATIONS.

The excavations for foundations of works shall be made of such depths and forms as the nature of the ground may require, and which the Company's Engineer will decide, without reference to the drawings. No work shall be commenced in any such excavations until the Company's Engineer shall have examined and approved of the same. During the progress of the work, the excavations are to be kept entirely free from water by pumping, or coffer-dams, or by adopting any provisions the Company's Engineer may direct. The earth arising from such excavations to be placed, when fit for such purpose, in the embankments or other part of the works where the Company's Engineer may direct; and in case no such depositary can be found, the Contractor will remove the same from the works entirely. As the works, whatever they may be, proceed in the excavations, the foundations to be filled in and punned round and about the masonry or brickwork, and the top smoothly levelled and made good to the satisfaction of the Company's Engineer. Where he may deem it necessary, the filling-in round and about the masonry or brickwork to be done with concrete. Where the ground is excavated to the level of rock, the same must be benched, to the satisfaction of the Company's Engineer, to receive the masonry or brickwork. More particularly where the excavations for the foundations of the brickwork or masonry are of any considerable depth, care must be taken to cut the ground as nearly as practicable to the correct form of the work, and to build close up to the ground so excavated. All foundation-works, whatever the same may be, to be included within the contract sum.

LIME, SAND, MORTAR, CONCRETE.

Lime.—The lime is to be of the best quality of well-burnt stone lime, in every respect to the satisfaction of the Company's Engineer; hydraulic lime, or where requisite, approved Roman cement, or pozzalano, shall be used wherever the Company's Engineer may desire it. The lime shall be fresh-burnt ground-lime, and no bag-lime will be allowed to be used. The lime to be ground under inspection when it is directed by the Company's Engineer.

If the lime is made by the Contractor, all the works connected therewith shall be open at any reasonable time to the inspection of the Company's Engineer; the kilns shall be erected where and in such manner as he may appoint; and any directions he may give relative to the lime-burning, or the grinding thereof, or as to the disposal of the same for the works, or the quantities, shall be carefully attended to by the Contractor.

Sand.—The sand is to be clean sharp sand, free from soil or any vegetable substance, and well screened, if required, through a screen not coarser than four meshes in the inch; and, if necessary, the sand shall be washed. As it frequently happens that there is great difficulty in obtaining good sand, and as the greatest importance is attached to this point, the attention of the Contractor is particularly directed to these conditions; and it must be clearly understood, that whatever may be the cost of obtaining clean sharp sand or ashes, these conditions will be rigidly enforced, and the question of the cost or difficulty of obtaining good sand or ashes, whatever this may be, will not be considered. Should the Contractor, notwithstanding this caution, allow any inferior sand to be used, the Company may deduct the whole, or any such proportion as the Company's Engineer may determine, of the cost of the masonry or brickwork in which such inferior sand has been used, from the contract sum. If ashes are used, they must be clean well-burnt furnace ashes.

Mortar.—Unless where the Company's Engineer may otherwise appoint, the mortar is to consist of one proportion of lime measured dry, and one and a half of clean sharp sand or ashes, the lime to be fallen and carefully screened through a screen not coarser than four meshes to the inch, and thoroughly mixed with the sand or ashes and water, in a pug-mill, or under edge stones, as the Company's Engineer may prefer; no water shall be added afterwards. Every precaution shall be used to ensure the best mortar, and any directions the Company's Engineer may give upon this subject shall be most carefully adhered to.*

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* There are few subjects on foreign works that will cause the Engineers and their Inspectors more anxiety than the obtaining of good mortar. During the summer months the rapid evaporation arising from the great heat admits of much more water being used than in our temperate latitudes. The making of large quantities of mortar at one time should be most carefully avoided.

In all cases where the quantity of brickwork or masonry at or near one place exceeds 300 cubic yards, or wherever the Engineer may require them, the Contractor will provide, if practicable, edge stones of proper diameter and weight to be used for the mixing of the mortar. The mortar to be used fresh, and on no account shall a greater quantity be mixed than can be used within twelve hours of its being so mixed. In all foundations, arches, and retaining walls, and where the work may be exposed to wet or damp, hydraulic lime of a superior quality, or cement approved of by the Company's Engineer, shall be used at his request. In all cases the lime and sand shall be measured in gauge boxes provided and always kept on the works for the purpose.

Concrete.—The concrete is to be made from one part of clean gravel, free from loam, clay, or vegetable matter, and having a proper proportion of small gravel as well as large; every attention must be paid to these proportions, so as to ensure their being sufficient small gravel to fill up the interstices between the larger stones: to this gravel shall be added an equal quantity of soft mortar, made of one part of approved hydraulic lime, measured dry, and two parts of clean sharp sand as above specified, the whole to be mixed in the following manner:—The lime shall be first mixed with the sharp clean sand into soft mortar, and this soft mortar mixed with an equal quantity of clean gravel in small heaps; these shall be turned over by shovelfuls and mixed into second heaps and the second heaps turned over by shovelfuls, and mixed into a large heap. When cement concrete is ordered to be used, the concrete is to be made, six parts of gravel, large and small, with a due proportion of sand, the whole well wetted with water and mixed by the shovelful, and to this shall be added one part of the best approved cement, and the whole prepared in the manner specified;* in no case will a larger proportion of gravel than above specified be allowed to be used. In every case where practicable, wheeling-planks shall be laid round the foundation-pits for the wheeling of the concrete into the pit, or cross stagings established for the purpose, and every precaution taken to prevent any earth or other matter from falling in with the concrete, and also to ensure its being teemed in so as to form regular layers in the pit of about one foot in thickness. In every case, before any masonry or brickwork shall be commenced on the concrete, the same shall be inspected and approved by the Company's Engineer.

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* There is always so much difficulty to get the ingredients of concrete well mixed together, that scarcely too much pains can be taken to ensure the thorough incorporation on which the value of concrete so much depends.

MASONRY.

STONE.—ASHLAR, BLOCK IN COURSE, RUBBLE, RANDOM RUBBLE.

BRICKWORK.

STONE IMPOSTS, STRINGCOURSE AND COPING, MOULDINGS, CAPS, ETC.

Stone.—All the stone used in the works shall be sound hard stone. For Imposts or Springers, Stringcourses, Copings, Mouldings, Caps, Quoins, &c., as well as in all Ashlar, and dressed Block in course masonry, the stone shall also be free from shakes, dry holes, and from all flaws of every description, to the satisfaction of the Company's Engineer.

When stone imposts or springers are used for bridges and viaducts, where Ashlar or block in course masonry is employed, they must exceed in thickness that of the arch by three inches below and two inches above the arch; and no stone shall be less than three feet in length, unless when requisite for obtaining the required dimensions. When there is more than one arch, at least four stones shall extend across the whole thickness of the pier. In cases of 'skew arches, the 'skew back must be truly worked to suit the oblique direction of the courses of the arch: the beds and joints must be chisel-dressed, and the faces fair-tooled, or with a margin draught of one or two inches, as may be directed.

Stringcourses, mouldings, copings, caps, or other such work, shall be worked true to the proper profile; no stone in the above to be less than three feet in length, and all to be carefully set, in a workmanlike manner, in mortar as above specified, to the satisfaction of the Company's Engineer; no underpinning being allowed, but the setting-bed must be true and level to receive such work. When required by the Company's Engineer, all such stones as the above shall have grout-nicks, two inches wide and two inches deep, in their side joints, corresponding with each other, so as to ensure a solid dowel being made in the following manner: that is, that they shall be run in with a pure cement of approved quality, without any sand, and run until the cement overflows.

When quoins are required to be used for any particular purpose, they shall be of such dimensions, and worked or dressed in such manner, as shall be shown or specified in the working drawings to be hereafter supplied.

ASHLAR MASONRY.

The term of Ashlar Masonry will be applied to wrought stone in masonry, where the courses shall be at the least twelve inches deep. The stone shall be of such approved quality as above mentioned, not less than four feet by two on the bed, and laid alternately as headers and stretchers. No Ashlar shall break joint or overlap by less than the depth of the course. All the joints and beds must be truly dressed and in parallel courses. All the face-stones for battering faces shall be worked with a proper bevel on the face of the stone; the joints and beds must fit close, and no underpinning will be allowed in any part of such work. The faces of such stones shall be either punched and with a one-and-a-half inch margin draft all round, or quarry-faced with the same margin draft, or merely quarry-faced and with a setting draft, as the Company's Engineer shall direct; chamfered joints shall also be wrought to such stones where directed. In all cases when required grout-nicks shall be cut, and these run with cement as above mentioned. This kind of masonry will only be required in particular cases, as in viaducts, heavy bridges, or tunnels. Similar kind of work will be required for sea-walls, and with increased dimensions in the stones. In all cases, mortar of the very best quality, made with approved hydraulic lime, or cement, and sharp clean sand, of a finer description than that in ordinary use, shall be made and used by special directions from the Company's Engineer, and to his satisfaction. When Ashlar is backed up by other kinds of masonry, the backing may be of unwrought stones, but of the same depth as the courses of Ashlar, and all joints squared; the whole set flush in mortar, well bonded together, and with the Ashlar facing. No joints in the backing to exceed three-quarters of an inch in thickness, and these to be well grouted.

BLOCK IN COURSE.

The block in course work shall be of stone laid in mortar, in courses not less than seven inches deep, and no stone shall be less than twelve inches by eighteen inches on the bed, laid alternately as headers and stretchers; and one-fourth of the length of each course shall consist of stones not less than thirty inches long, measured from the face of the work to the interior, laid as nearly equidistant as possible, so as to effect a perfect bond with the rubble backing. Whenever the block in course is required in deeper courses than the above, or of larger stones than the medium size here specified, the bond stones must be proportionately increased in length. Every course to be of the same depth throughout.

The beds and joints must be carefully hammer-dressed true and square, and the joints and beds pick-dressed for at least nine inches from the face. The whole will be laid in mortar and backed with rubble.

Wherever through courses of block in course are shown or mentioned on the drawings, or where any piers are to be built of solid block in course, the beds and joints of the stone are to be pick-dressed true and fair, and no packing or filling with rubble will be allowed.

In all block in course facework, where, from the manner the stones have been obtained from the quarry, some of them are broader at one end than at the other, one third at the least of all such stones shall be dressed and set in such manner that the larger end shall form the back of such stone, and be set in the inside or at the back of the work.

ARCHES.

Stone arches will be either of Ashlar or block in course; the term "Ashlar" will be used where the depth of stones forming the arch shall exceed two feet, and the term "block-in-course arch" where they are less than two feet. In all cases the beds and joints of the arch-stones shall be truly summered and accurately worked, and the beds in the direction of the radius of the arch. Where Ashlar quoins are used to brick arches, great care must be taken to prevent unequal settlement; such quoins must have their joints at the face and underside chamfered; they must have a 1¼ inch margin draft, in the inside of which the face and the intrados must be punched.

When the arches are built askew, the courses must all be laid spirally at right angles to the face of the arch.

Every care must be taken to cut the stone in the spandrils, so that they shall fit the extrados of the arch.

The whole of the arches and backing must be covered with puddle made of gravel and clay, or concrete, as the Company's Engineer may direct.

The laggings of all centering shall be adzed when requisite, to procure a true and uniform curve.

RUBBLE BACKING.

The rubble backing must consist of flat bedded stones as large as can be obtained; the whole must be carefully fitted together, obtaining as much bond as practicable, and made solid, laid in mortar, and brought up to a level surface at every course of the face work, and after the next course of face stones is laid, the interstices must be completely filled with thin mortar and worked about until every crevice is filled perfectly solid.

RUBBLE WORK.

Where the Company's Engineer allows rubble to be used for the entire work, both on the face and in the interior, the stones laid in mortar must be carefully fitted together, so as to obtain a perfect bond. No stone must contain less than one-third of a cubic foot; the stones in the face of the work to be carefully hacked and the joints pointed. The work to be brought up in courses not exceeding fifteen inches in depth, and well flushed with soft mortar carefully worked about until every crevice is filled perfectly solid.

RANDOM RUBBLE.

Where the Engineer may allow random rubble to be used in any of the masonry, at least one-third of the number of the stones shall be not less than three-quarters of a cubic foot each, from which all sharp edges and corners shall be hammered off; another third of the stones shall be not less than one-third of a cubic foot each. These shall be distributed as equally as may be throughout the work, and with every practicable attention to obtain bonding of the stones, and laid in mortar; the remaining third being used for filling in. The work shall be brought up in courses not exceeding fifteen inches in depth, and every course thoroughly flushed with soft mortar. Courses of brickwork or block in course, whenever required by the Company's Engineer, shall be laid in this work in the manner directed, and whenever these will have to be set, the random rubble shall first be brought up to a well-filled solid bed, to the Company's Engineer's satisfaction, to receive the course of brickwork or block in course, which shall not be less than six inches deep.

RUBBLE DRAINS.

Substantial rubble drains, one foot by one foot in the clear, shall be made at the back of all abutments, wing-walls, retaining walls, or whenever required by the Company's Engineer, and in such manner as he shall direct, in order to provide thorough drainage at the back of all the work. This will refer to brickwork as well as to masonry.

BRICKWORK.

The bricks used in all the works shall be the best new, sound, well-shaped, hard-burnt bricks, free from all defects, to the satisfaction of the Company's Engineer; and in no case shall bricks of different dimensions be used in one work. All the best-shaped and best-coloured bricks shall be reserved for facework.

The brickwork, unless when required by the Company's Engineer, shall be set in mortar as above described.

No four courses with three joints must exceed in thickness, when built, three-quarters of an inch more than the same bricks measured when piled on each other without mortar.

The bricks must be well saturated with water, and every bricklayer shall be supplied with a trough of water, in which the bricks before using shall be kept.

No bats are to be used, unless where it may be necessary for obtaining the required dimensions of the different courses.

All the upper courses of all brick cornices, copings, plinths, or offsets of every sort, which are exposed to the weather, shall be set in approved cement.

The bricks shall be bedded sound, and flushed with mortar, and except in arches, to be grouted at every second course with a grout composed of two parts of sharp clean sand to one of lime, with a proper quantity of water.

The work must be finished in all facework, with a neat drawn joint, and pointed; the whole to the satisfaction of the Company's Engineer.

Brick arches shall be set in mortar, or in cement, mixed with an equal portion of sharp clean sand, as the Company's Engineer may direct.

In setting the bricks in arches, they are to be well pressed into their beds, so as to squeeze the mortar out and leave the joint thin.

All the bricks in arches are to be laid with properly radiating beds, and the bricks forming the skew backs shall be all properly cut. The bricks at the spandril walls must be cut, so as to fit the curvature of the arch.

The arches of the bridges, viaducts, and culverts, shall be covered with good puddle, made with gravel and clay, or with concrete, as the Company's Engineer shall direct.

BACKING.

All brickwork or masonry shall be backed up with good dry earth, loamy when attainable; if with clay, an equal portion of gravel or sand shall be mixed with it; this backing shall be at least five feet wide, and brought up in layers of six inches deep each, and to be well punned before an additional layer is laid on. The head of the punner used shall be of iron, and not exceed ten pounds in weight. The earth for backing shall be wetted where required.

WOODWORK, AND WROUGHT OR CAST IRON USED THEREIN.

All timber made use of in girders, piles, tiebeams, walings, struts, ties, braces, wall plates, sills, corbels, planking, or for any purpose whatever, shall be of the best Memel, or of a kind equivalent thereto, and in every respect satisfactory to and approved by the Company's Engineer.

All timber used shall be straight, clean, sound, and free from shakes, sap, and large unsound knots, well seasoned; and no timber fresh from pond, or that has been lying in water, shall on any account be introduced in any of the works until it has been thoroughly and properly dried, to the satisfaction of the Company's Engineer.

All oak required shall be of the best and soundest English heart of oak.

All rough timber work to be executed in the best style of rough carpentry, that is, undressed in all the main scantlings, but wrought perfectly true at all surfaces in contact, and at all joints, all mortices and tenons, and housings, or other such work, truly wrought and fitted in the best style of workmanship, all bolt holes truly and accurately bored, and of proper dimensions.

All planking to be well and truly laid to gauge where required, spiked with spikes twice as long as the planks are thick, and two of them at each crossing. No planks newly sawed will be allowed to be used for this purpose, and all planking shall be laid in the manner directed by the Company's Engineer. All planking for bridges to be covered to the depth of one inch with sand mixed with hot well-boiled tar, previous to any ballast being laid on.

All wrought timber work is to be executed in the best style of workmanship to the satisfaction of the Company's Engineer.

All piles are to be well and truly shod with sound and well-made wrought-iron shoes, of at least twenty pounds weight, and to be driven until they will not go more than one quarter of an inch at a blow from a monkey of a ton weight falling eight feet, or to any other limit of resistance which the Company's Engineer may direct or approve. All piles damaged by driving shall be drawn and replaced by the Contractor or shall be cut off and left, if required by the Company's Engineer. In the case of rock interfering with the driving of piles, the upright must be firmly secured to the rock, in a manner approved of by the Company's Engineer, who will determine whether the ground is fit for piling or otherwise.

All timber and ironwork, straps and fastenings, used in any bridges or other works, shall receive two coats before fixing, and one coat after fixing, of creosote, satisfactory to the Company's Engineer, every precaution being taken to ensure that the timber is thoroughly dry before the creosote is laid on.

All wrought iron used in woodwork for any purpose or in any manner whatsoever shall be of the best S. C. crown iron, or of such description of iron as shall be in the opinion of the Company's Engineer of equal quality. The greatest care must be taken to ensure perfect soundness in any welds that may be required, and all workmanship, whether of forging or fitting, must be of first-rate quality.

All such ironwork shall be of the dimensions shown on the drawings supplied by the Company's Engineer, and when such ironwork has been omitted to be shown on the drawings, the Contractor will supply it in the works at the request of the Company's Engineer.

The heads of all bolts must be forged in one with the bolts, and must be equal in thickness to the diameter of the bolt. All nuts must also be of the same thickness, and the thread of all nuts and bolts must be well and deeply cut, and in every respect to the satisfaction of the Company's Engineer, and to be countersunk where he may require, or when evidently requisite from the nature of the work.

All cast ironwork shall be of good grey metal, equal to the best London castings, perfectly clean and sound, and true to pattern, and satisfactory to the Company's Engineer.

When required, or when the iron has not been creosoted, it is, after being cleaned, to be painted four times in oil, and left of an approved colour; and in all cases every precaution shall be taken to provide against rust, to the satisfaction of the Company's Engineer.

LEVEL-CROSSINGS.

For level-crossings of roads drawings will be provided by the Company's Engineer, descriptive of the manner in which they are to be crossed, and of the appliances to be provided and laid down by the Contractor to the satisfaction of the Company's Engineer; as also of gate lodges where the Company's Engineer shall direct that a lodge is to be built.

ROADS AND AQUEDUCTS.

All roads interfered with by the railway, or that have been used during the construction of the works by the Contractor, shall be repaired and metalled to the satisfaction of the Company's Engineer with good gravel or hard stone broken small. Any pavement taken up shall be substantially restored; and all roads shall be satisfactorily drained, and in all respects put in good condition satisfactory to the Company's Engineer. Any directions on this subject given by him to the Contractor during the progress of the works shall be immediately attended to and carried into execution.

All public or private aqueducts and watercourses interfered with in any way by the works shall be restored as speedily as practicable, and put into good condition to the satisfaction of the Company's Engineer in all respects; and all such provisional measures as he may deem requisite shall be adopted by the Contractor.

Either as regards roads or aqueducts, or watercourses of a public character, or belonging to private individuals, the Contractor is to be responsible as regards all claims for damages made and proved to the satisfaction of the Company's Engineer, for repairs or for any other cause whatever. It shall be in the power of the Company's Engineer, after having given ten days' notice to the Contractor, to pay or cause to be paid any amount claimed in these respects, should he consider that the Contractor neglects to settle the same, and to deduct the amount from the amount to become due on the next certificate or certificates, as he shall deem proper.

TUNNEL.

The tunnel works will consist of the whole of the works requisite for completing the tunnel or the tunnels should circumstances appear such that more than one can be advantageously made, of which circumstances the Company's Engineer is to be the only judge; and will include all shaft work and all the contingent works that may possibly arise connected therewith; the driving of headings, the making the whole of the complete excavations, including sanctuaries, all timbering and centering, all works of masonry or brickwork, including tunnel fronts; all filling, packing, or backing; all pumping out of water, and all the ventilating of the works; all machinery, centering, labour, and workmanship; and all material that may be required for the substantial completion of the work. The tunnel is to be made for a single line of rails.

Whenever the Company's Engineer may deem it necessary, the Contractor shall put in a lining of brickwork or masonry of such thickness as the Company's Engineer may direct; and such work, including arching, side walls, inverts, drains, or counterforts, underpinning, backing, or filling, must be done in the most substantial and workmanlike manner, cement to be used instead of mortar whenever required by the Company's Engineer, who is to be in every respect satisfied as regards the quality of all materials and the whole of the workmanship of such work.

Sanctuaries, lined where required, will be made about one hundred and fifty yards apart, alternately on each side of the line. The form and exact position of these sanctuaries will be determined by the Company's Engineer during the progress of the works, who will also decide when and in what manner and to what thickness they are to be lined.

In sinking the shafts, all pumping, lining with brick or stone in cement, or all timbering or cast-iron curbs, must be provided when the Company's Engineer may deem them necessary.

The rate of progress of all the excavations of the tunnel immediately in advance of the lining must depend on circumstances, and will be determined by the Company's Engineer.

In the making of all the excavations the Contractor will take every care that no more be excavated than is required, more particularly when a lining of brickwork or masonry is to be built, excepting where absolutely necessary from the nature of the ground or rock.

In no case shall any masonry or brickwork rise more than nine inches without the back being filled perfectly solid. The Contractor is to appoint one man for every length of masonry or brickwork, whose duty it shall be to attend to this filling, which is to be carefully packed in dry material, and where necessary it shall be done with light beaters made on purpose.

Every precaution will be taken to properly draw all bars and planking, but where deemed necessary they must be left.

All excavation in advance of brickwork to be carefully supported according to the usual practice by sill props or shores, bars and poling boards, the dimensions and dispositions of which will all be subject to the approval of the Company's Engineer.

The roof, sides, and invert shall all be cut of the finished size of the work as near as practicable.

The form and dimensions of the tunnel and of the tunnel fronts shall be according to drawings to be provided by the Company's Engineer, but who shall have full power to make any alterations therefrom that he may deem necessary as the works proceed.

The Contractor is to establish the most complete systems of ventilation, and keep all the works dry. All damages that may arise from slips or crownings, or from whatever cause arising, must be repaired and the work made good by the Contractor.

All blasting operations shall be carried on with due care and with all possible precautions, and all the means, tools, implements, and materials necessary and in ordinary use to ensure the proper progress of the works and safety from accidents shall be provided.

The Contractor shall provide and pay an able or competent foreman, who shall have no other duties to perform than attending to the tunnel works, and who shall be an experienced miner in similar operations.

All contingent works for which necessity may occur during the progress of the tunnel, and in any way arising from or connected therewith, must be executed by the Contractor to the satisfaction of the Company's Engineer.

When the tunnel is delivered over to the Company, the Contractor shall have all the works in the most substantial condition and state of repair, to the satisfaction of the Company's Engineer, who will otherwise not receive them under any circumstances whatever.

WORKS OF WROUGHT OR CAST IRON.

The wrought ironwork shall in all cases be of the best description and manufacture, and put together according to the best principles of workmanship and by experienced men in their several trades, to the satisfaction of the Company's Engineer, who is to be the only judge of the proper execution of such works during their progress and when they are delivered up by the Contractor to the Company.

All the wrought ironwork is to be double-fagoted iron, whether hammered or rolled, and is to be capable of bearing a tension strain of fifteen tons to the square inch, with a permanent extension in length not exceeding $\frac{1}{100}$ of an inch per foot.

All bolts to be made from one piece and the head of every bolt forged in one with the bolt; to be straight, round and well shaped, and all threads cleanly and deeply cut. The rivets as well as the bolts are to be of iron of the above specified quality, and capable of bearing the above-mentioned strain; and all riveting work shall be done by well-experienced workmen, who shall be supplied with all facilities. All bolt-holes shall be truly drilled. All nuts and screws used for the works are to be clean cut, of proper dimensions, thoroughly good in quality, and made to fit well.

All the work shall be executed and put together in the most workmanlike manner, and shall in all respects be to the satisfaction of the Company's Engineer.

All wrought ironwork to be coated with hot linseed oil, and when dry shall receive two coats of red lead, of a quality approved by the Company's Engineer, and where requisite shall be painted when in place twice in oil colour which the Company's Engineer shall approve of.

Any cast ironwork required shall be in quality, form, and dimensions approved by the Company's Engineer, and to be clean, sound, and perfect castings, coated with hot linseed oil, and with two coats of paint, and to be left a colour approved of by the Engineer.

In all cases the wrought or cast ironwork for the railway shall be truly executed according to drawings and written instructions from the Company's Engineer, and none other, from any cause whatever, will be allowed to be introduced into the works of the line.

All girders, plates, bars, angle and T-iron, columns or pillars, or any wrought or cast iron whatsoever, shall, when deemed requisite by the Company's Engineer, be tested in any reasonable manner other than that above mentioned; and the Contractor will supply means and labour for applying such tests. And any girders, plates, bars, columns, or pillars, or any wrought or cast iron whatsoever, which, on the application of the tests, shall be unsatisfactory to the Company's Engineer, either as regards material, manufacture, or workmanship, will be rejected, and the Contractor will find new at his own cost.

TIMBER JETTIES, AND CREOSOTING.

For timber injetties and all sea-works constructed entirely or in part of timber, the operation of creosoting must be applied in all its integrity to the whole of the timber used for piles, walings, sills, struts, braces, plankings, or for whatsoever purpose the timber may be applied.

The timber is to be placed in a wrought-iron tank of sufficient capacity, and submitted to the action of a vacuum, created by an air-pump, and sufficient to drive all sap and moisture out of the timber.

The creosote, of which the quality shall be approved by the Company's Engineer, shall then be turned on to the timber in the tank, and driven into it by means of a force-pump, under a pressure of not less than one hundred and forty pounds per square inch, and until the weight of every cubic foot of timber shall be greater by ten pounds than when it was first introduced into the tank.

The operation shall be carried on under the superintendence of the Company's Engineer, through an Inspector appointed to watch over the work, which shall only be carried on in his presence; and all the timber taken out of the tank and approved by him shall be branded and registered by him, and kept under his charge until delivered to the Contractor for the purpose of the works, for which no other than such branded timber will be allowed to be used.

The Contractor will establish for this purpose a complete set of works, with steam-engine and all apparatus fitted up in the most complete and efficient manner, and on the most approved principles in practice, to carry on the operation of creosoting to the satisfaction of the Company's Engineer.

With every batch of timber inserted in the tank, one log averaging fifteen inches square, shall be introduced after having been carefully weighed: and such batch of timber shall only be considered sufficiently creosoted when this log shall be found to weigh ten pounds heavier per cubic foot than when first introduced into the tank.

Under the above conditions, the Contractor will be at liberty to carry on the creosoting in England.

The piles shall be of clean, straight, sound timber, free from shakes, sap, or other defects, and equal in quality to Memel, in the opinion of the Company's Engineer.

Each pile shall at one end be carefully adzed, nearly, but not quite to a point, which shall coincide with the axis of the pile; which shall then be firmly and accurately shod with a well-made wrought-iron shoe, weighing not less than thirty pounds, which shall be secured to the pile by eight iron screws, not less than one half inch in diameter.

Great care is to be taken in pitching the piles in the exact positions shown on the drawings; and any pile driven out of place shall be drawn and rejected, at the Contractor's cost; or, by direction from the Company's Engineer, it shall be left and another pile, at the Contractor's cost, driven as near to it as possible. Every pile shall be hooped in a workmanlike manner, with a sound wrought-iron hoop of at least two inches by half an inch.

When scarfing is necessary, no scarf shall be less than seven feet long for the piles, and such scarf shall be well bolted and keyed in a manner and with such means as the Company's Engineer shall approve of, and in all respects in a workmanlike manner; and the heads and nuts of bolts shall all be countersunk. No pile shall be pitched unless previously examined and passed by the Company's Engineer.

The piles shall be driven with a monkey weighing not less than a ton, and until each pile refuses to go any farther than one-half of an inch from three blows of the monkey, falling from a height not less than eight feet, or to such other limit of resistance which the Company's Engineer may deem sufficient.

All wrought iron used shall be steeped, while hot, in creosote.

All the other timber-work shall be done according to the drawings supplied by the Company's Engineer, or in strict conformity with the instructions given by him from time to time, the whole in a truly workmanlike manner such as he shall approve.

The permanent way is to consist of a single line of way, with all the sidings which the Company' Engineer shall deem requisite; and the gauge shall be four feet eight and a-half inches, or that known as the narrow gauge. And the materials of the permanent way shall consist of ballast, rails, chairs with compound-chairs, and guard-rails where deemed necessary by the Company's Engineer, at level-crossings, spikes and keys, fish-plates, bolts and nuts, and sleepers, switches, points, and crossings.*

The ballast is to consist of clean gravel, screened for the rejection of all large stones, and the Contractor shall take all possible pains to procure the same; and where from necessity any other material shall be allowed by the Company's Engineer to be used as ballast, it shall consist of well-burnt clay, cinders, and stone broken small enough, the whole to be approved by the Company's Engineer before being used.

As regards the other materials (excepting sleepers) for the permanent way, they shall not be provided and charged as material to the Company until they have been ordered by the Company's Engineer and shipped; and such order shall always be given at least six weeks before the time for shipment. And these materials shall always be examined by the Company's Engineer in England, and his written certificate of approval obtained previous to shipment; such written certificate of approval to be handed to the Company's Secretary, with the invoice, and duplicates of certificate and invoice sent to the Company's Engineer in Turkey.

In all cases such written certificate of approval to be obtained as regards all the plant and material of the Company, previous to the shipment by the Contractor; and no material will be paid for or received without such certificate.

The process of manufacture of all permanent way materials shall be open at all reasonable times to the inspection of the Company's Engineer, or of any agent he may appoint; and any instructions he may give shall be strictly adhered to.

The rail shall be throughout the length, and particularly at the ends, of the pattern or stamp template kept in the Company's office, a duplicate of which is delivered to the Contractor at the signing of the contract, and is to be of sixty-five pounds per lineal yard, and in all respects of first quality of material and manufacture; and to be guaranteed by the Contractor, for three years after being laid down, against all breaking, crushing, splitting, or laminating; and in case of any such defects within the said period in any of the rails, the Contractor is to replace them. The *fixed length* of the rail shall be eighteen feet; but one in twenty will be admitted measuring only fifteen feet: one rail in every ten will also be admitted measuring three inches longer and shorter than the fixed length of eighteen feet; but no other variation from these lengths will be admitted beyond one-tenth of an inch. The rails must exactly fit the chairs.

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* See one of the following Chapters on Permanent Way.

Each rail shall have two holes at each end, for the reception of the bolts for the pair of fish-plates by which each rail-joint is to be secured.

The invoice shall specify the exact lengths of the rails, in order that they may be separately classed. The iron employed in the manufacture of the rails shall be No. 2 mine iron, free from cinders, so that the rails may correspond with No. 3. All rails showing any flaw or defect will be rejected. They shall be sawn at the ends, which, when finished, shall be perfectly square and sound. Any rails that may be bent shall be straightened by means of a screw, and not with the hammer.

The chairs shall be cast from No. 2 strong grey iron, and run from the cupola; they shall weigh 21¼ lbs. per chair. The chairs are to be clean, sound, and perfect casting, and will be subject to the entire approval of the Company's Engineer; and any that he may disapprove of, whether from imperfection of material or from the manufacture, shall be rejected, and new chairs will be provided by the Contractor.

The keys shall be of compressed oak of the best quality, true to shape and form, not less than five inches long, and thoroughly saturated with creosote.

The pair of fish-plates at each joint shall weigh twenty-eight pounds, fit true to the tables of the rail, and be in every respect of the best material and manufacture.

The bolts and nuts shall be of the best quality, true in form and dimensions, with the thread clean and deeply cut, and the bolts shall be three-quarters of an inch in diameter.

The sleepers are to be of larch, or of some timber of the country approved by the Company's Engineer, and to be not less than eight feet and six inches long, and full ten inches by five inches at the smallest end when half round; if of squared timber they shall be of the same length, and not less than nine and a half inches by four and a half inches. The Contractor will be at liberty to make his selection as to which of these dimensions he chooses, but sleepers of both dimensions will not be allowed to be used. All the sleepers will have to be thoroughly creosoted to the extent of at least eight pounds of creosote to every cubic foot of timber. The superintendence of the work of creosoting will be under the immediate charge of the Company's Engineer through inspectors, in the absence of whom no creosoting operations will be carried on; and the Company's Engineer will have the power of appointing and discharging a foreman, to be paid two pounds sterling per week by the Contractor, at every station where the sleepers are being creosoted. The quantity of creosote in the sleepers shall be tested by taking the average weight and cubic quantities of a number of sleepers, and every cubic foot of the creosoted sleepers shall weigh at the very least eight pounds more than a cubic foot of sleeper uncreosoted.

The average distance of the sleepers shall be two feet and eight inches from centre to centre of sleeper; but at the joints of the rails the sleepers shall only be two feet from centre to centre, with the joint half-way between them; and every eighteen feet length of rail will have seven sleepers.

If the half-round sleepers are used, each of the sleepers must be planed true and out of winding quite across for a space of eighteen inches in length for the full and fair seating of the chair, and a hole for one spike bored in each sleeper for one of the chairs, and this hole must be bored with great accuracy to ensure its right position.

When the sleepers have been thus planed and bored, they are ready for laying.

The rails, chairs, and sleepers being distributed along any portion of the line which has been thoroughly well ballasted, and having full fifteen inches of well-settled ballast on it, and the fastenings ready in dry boxes or casks, the plate-laying is to commence by setting out and spacing the sleepers at the joints of the rails and laying them square across the line, in proper trenches made in the ballast, so that there shall be full a foot of ballast underneath each sleeper.

The chairs near the joints are then to be spiked down with one spike in the hole previously bored in each sleeper: this being done in several sleepers, the rails are then to be laid in the chairs, spiked down, their ends adjusted, and the distance-piece of sheet iron or copper introduced between the joints; the wedges are then to be driven to confine the rails to their proper positions, and the fish-plates fitted on but not tight, and one line of rails will thus have been placed in position.

Whilst this is in progress the chairs near the joints are to be placed upon the planed surfaces at the other ends of the sleepers, as nearly as practicable in their true positions, the rails introduced as before, adjusted to situation and distance of ends, and the wedges driven. The two lines of rails being thus laid on the sleepers, with one line fixed by single spikes, it now remains to bore the other sleepers near the joints of rails, and drive a single spike into each of them to bring the line into gauge.

To do this, wrought-iron distance-gauges, each having been approved, tested, and stamped by the Company's Engineer, are to be fixed upon both lines of rails square across; near the joints; the holes are to be bored through the inside holes of the chairs for the spikes, which, on being driven, fix down the chair firmly with the rails in perfect gauge, the distance-gauge not being taken off until the spikes are driven.

Whilst this part of the plate-laying is being carried on, with the chairs and sleepers near the joints and the rails fixed in position, the distances are to be spaced out for the intermediate sleepers, and the sleepers introduced under the rails and squared across the line at a distance of two feet and eight inches from centre to centre, whilst the sleepers near the joints are only two feet from centre to centre. The chairs are then to be well bedded on the sleepers, which are to be in all cases kept free from sand between them and the chairs.

The chairs at the bored holes are now to be spiked fast down, the wedges driven, the opposite chairs wedged, the distance-gauges put on, the sleepers truly adjusted, the inner holes bored, and the spikes well and carefully driven with a proper hammer and drift. The gauges may then be taken off, the remaining spike-holes bored, and the spikes driven as before.

The rails, chairs, and sleepers being all adjusted and fastened, every sleeper is to be well and soundly underpacked with ballast, so as to bring the upper surface of the rails into perfect line and level, and the spaces between them, and outside the rails to the extent of the ballast to be well filled-in and boxed-up to the underside of the upper flanch of the rails at their outer edge—that is, within one inch of the top of the rails,—and neatly trimmed off in such manner and form for drainage as shall be directed by the Company's Engineer.

As the work of underpacking proceeds, the fish-plates may be introduced and tightened up.

Every care must be given to laying the permanent way in a sound and proper manner, and should the Company's Engineer find it requisite, he will place on inspectors to superintend the work.

On curves, due care will be given to fix the outer rail at a proper degree of superelevation above the inner rail.

The Contractor will be allowed to draw materials along the Permanent way, but in so doing he must take care to keep the sleepers well covered, to protect them from injury, in such manner as shall be satisfactory to the Company's Engineer. And it is to be distinctly understood, that any sleeper, chair, or rail, or other matter, injured during the progress of the works, is to be renewed by the Contractor at his own cost.

MAINTENANCE.

The whole of the works of the railway, without any exception whatever, are to be maintained by the Contractor, at his own cost, for twelve calendar months after the opening of the different sections as they are handed over to the Company, in good order and condition, to the satisfaction of the Company's Engineer, and without causing any interruption whatever to the traffic of the railway.

The whole of the permanent way of the line on the several sections is also to be maintained by the Contractor, for twelve calendar months after they have been opened for public traffic, in good working order, true to levels, smooth and even, and well boxed-up with good ballast, to the satisfaction of the Company's Engineer, and without any interruption to the traffic; and all materials and all labour and workmanship of any kind whatever requisite for such maintenance of works and permanent way, to be provided by the Contractor at his own cost. At the end of each of the twelvemonths after the opening of the different sections, the whole of the line and works are to be delivered up by the Contractor in such good order and condition as shall be in all respects satisfactory to and approved by the Company's Engineer. Should it happen that any work of repair or renewal is in course of execution at the expiration of twelve calendar months on the different sections, such work is nevertheless to be completed by the Contractor at his own cost.

Any works of maintenance, repair, or renewal, required by the Company's Engineer shall be commenced by the Contractor within forty-eight hours' notice being served upon him, and shall be duly carried on until completed; and should the Contractor then neglect commencing and duly carrying on such work, the Company's Engineer shall be at liberty to carry on such work at the Contractor's expense.

The above stipulations are without prejudice to the before-mentioned condition, whereby the Contractor guarantees the quality of the rails for a period of three years from the opening of the several sections for traffic.

GENERAL CONDITIONS.

The Contractor is to execute the whole of the works, and is to provide all plant and materials of every kind that may be requisite for the due and proper execution of all the works comprehended under this Contract; and he is to take upon himself all risks and all responsibility, as to any contingencies whatever that may arise in respect of the works. He is to make good at his own cost any works that may fail from any cause whatever. The Contractor will construct the works in conformity to all the terms and conditions of the Agreement for the Concession, and will construct and complete all public or private road-bridges and crossings, all river-bridges and culverts, viaducts, tunnels, and all other works that may be required for the complete forming of the railway, and all accessory works under the Contract and the Agreement for the Concession: and all the works shall be constructed of such materials as the Company's Engineer shall direct, and according to drawings and instructions, which he shall provide from time to time during the progress of the works, to suit each particular case; but it is understood that so far as the Company's Engineer shall deem it proper under the Contract and the Agreement for the Concession, he will allow the Contractor to use such materials as may be most readily obtainable, provided always that the Company's Engineer considers such materials suitable and proper for the construction of substantial work on a first-class railway.

During the progress of the works, the Contractor is to provide all requisite temporary bridges, crossings, roads, watercourses, and drainage, for keeping up communications and drainage. All temporary bridges, crossings, and roads, to be sufficiently lighted and watched; and the Contractor is to be responsible for any damage that may arise in consequence of his neglecting to take such precautions.

The works will be carried on under the direction of the Company's Engineer, who will have full power in all matters relative to the mode of carrying on the works, or their design, and as to the nature and quality of all the materials used, or workmanship executed; and his instructions are to be in all things acted on by the Contractor. And he is to have power to reject and condemn any materials or workmanship that he may deem unsuitable; and any materials so condemned and rejected shall be removed and replaced by the Contractor at his own cost to the Company's Engineer's satisfaction. And with regard to materials condemned, the Contractor shall commence the removal of the same from the Company's premises within twenty-four hours after he shall have received notice thereto from the Company's Engineer; and the work of removal of such condemned material is to proceed continuously and diligently until the whole shall have been carried away, and if the Contractor neglects doing so, then the Company's Engineer shall have power to remove such material at the expense of the Contractor, who shall have no claim whatever for any loss he may incur in any way therefrom, nor will the Company be answerable for any loss of such material.

The Contractor is to give his own constant personal superintendence to the works, or to employ an agent to represent him, who shall be approved of by the Company's Engineer. He must also have an office on or near the works, open at all reasonable hours, to receive instructions or communications from the Company's Engineer, and where the delivery of all written instructions, or orders, shall be considered as a service upon him.

The agent is to be paid a salary by the Contractor, but on no account whatever, either entirely or in part, by any commission on or share of the profits, unless he be a partner of the Contractor's.*

The Contractor is also to keep on the works such sub-agents as the Company's Engineer may deem necessary; and all instructions given to the agent or sub-agents shall be considered as given to the Contractor.

The Contractor is also to employ and maintain on the works approved foremen for the different departments of the service.

No part of the works is to be sub-let, without the knowledge and consent of the Company's Engineer.

The Contractor will, at his sole expense, take down and reconstruct, to the satisfaction of the Company's Engineer, any works that he may consider improperly executed.

The Contractor shall also remove from the works any foreman or other person to whom the Company's Engineer may object.

The Contractor will provide all the ranging-rods, stumps, stakes, tools, and labour which the Company's Engineer may deem necessary, for setting-out the line, and the works during their progress, and all labour for carrying instruments from place to place; and at his request the Contractor will maintain upon the works any particular men appointed for this work, who shall always be at the disposal of the Company's Engineer, without making any additional charge for the same; and in the same manner the Contractor will provide all requisite labour for measuring-up the work from time, to time as the Company's Engineer may deem necessary.

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* This will be found to be the best way to prevent a great deal of evil on public works in the East, notwithstanding the best intentions of the Contractor and all the endeavours of the Company.

During the execution of the works, or the period of the Contractors maintaining of the same, as herein specified, he will be held liable for any damage that may occur through the neglect of himself, his workmen, or others; for want of proper fences, by cattle straying, by trespass or otherwise, or for damage that may arise at any road-crossings, for want of proper provisions or precautions being made for the safe and convenient means of passage by all persons, cattle, caravans, or vehicles using the same; or for want of the proper means of drainage of the lands passed through.

The Contractor will not at any time remove from the works any plant or material, without permission in writing being first obtained from the Company's Engineer, nor until he shall have certified that the works have been duly executed under the Contract.

The Contractor undertakes all responsibility as regards any information, plans, sections, or drawings, supplied to him by the Company's Engineer.

As regards quantities and prices for the purposes of certificates, the Contractor and the Company's Engineer will agree thereupon as far as practicable before the works are commenced; but where this has not been done, the work shall be measured-up jointly by the Contractor and the Company's Engineer, and the quantities shall be signed by both as accepted. The Engineer will then set a price upon the work, which shall be as nearly as practicable in just proportion, in his estimation, to the value of any work already done or hereafter to be done on the section to which such work belongs.

The Contractor will deliver, forty-eight hours before the signing of the monthly certificates, a correct and properly classed return of all the labourers, workmen, mechanics, and others, who have been engaged on the works during the month; nor shall the Contractor be entitled to his monthly certificate until after the delivery of such return.

The Contractor will make no claim, and will have no right to compensation from the Company, in the case of unforeseen difficulties or events arising beyond the Company's control, by which the works may be delayed, stopped, or abandoned.

The Contractor will provide, under the Contract, all the hutting and dwellings which shall be deemed necessary for the accommodation of the workmen by the Company's Engineer; and all such accommodation shall be erected with due attention to the health of the men; and the Company's Engineer shall have full power to determine upon the locality, description, and quantity of the hutting, and at any time to examine into the condition of the same; and the Contractor shall be bound to carry out all his instructions relating thereto, with the same attention and promptitude as for any of the works of the railway. Wherever the Company's Engineer may deem it necessary, the Contractor will provide substantially built weather-proof huts for the accommodation of the Company's Engineers and Inspectors, never to contain less than two, nor more than four rooms, the former of which shall not contain less that 250 square feet, and the latter 400 square feet on the plan, with the requisite glazed windows, deal doors, and boarded floors; they shall not be more than fifteen miles apart, and shall be satisfactory to the Company's Engineer; and, in all cases where practicable, these huts shall be built within about 100 yards of the workmen's huts.

The Contractor will pay the workmen weekly their full amount of wages in the current coin of the realm, and on no account whatever shall any payment be made by tickets, goods, or provisions of any kind, or in any other way than in the current coin. The Contractor will not allow any person whatsoever in his employment to supply the workmen with any goods, provisions, or liquors, nor shall he employ any person whatsoever to do so; and should any one belonging to him contravene against this order, the Contractor will immediately dismiss him at the request of the Company's Engineer.

In the event of the Company's Engineer deeming it requisite or advisable to erect any temporary establishments on the site of a workmen's camp situate near any locality of a future station, the Contractor will provide all necessary labour and materials, and construct the same according to instructions given by the Company's Engineer, always provided that the actual expense of the same do not exceed two hundred pounds sterling for any one establishment, and that such establishments do not average more than two or exceed in cost more than four hundred pounds sterling on forty miles, and that the Contractor will be at liberty to use for such purpose, and under the superintendence of the Company's Engineer, any timber, iron, or other suitable material which the Company may have on the works. In the event of such establishments being sold at the conclusion of the works, the Contractor shall be entitled to receive the full benefit of the sale.

All materials invoiced to the Company by and on which any payments shall have been made to the Contractor, shall thereby become the Company's absolute property. With respect to the delivery of such materials to the Company, the Contractor will land the same free of all charge for freight, demurrage, or all expenses of landing, stacking, or storing of the same on or near the works, according to instructions furnished by the Company's Engineer, and so that all such materials shall be delivered in good condition into his charge free of all expense of any kind, up to which time the Contractor will be held responsible for such materials, and will make good any loss or damage that may have been incurred thereon from any cause whatever arising. After having made a satisfactory inspection of these materials, the Company's Engineer will give the Contractor a receipt for the same, and which alone shall be the Contractor's release from responsibility as regards the due delivery of the Company's materials.

The Company's materials are only to be used in the actual construction of the Company's permanent works. On the requirement of the Contractor, stating the purposes to which the materials are to be applied, the Company's Engineer, if satisfied therewith, will deliver to the Contractor the materials required, and for which the Contractor will give a receipt, stating the purposes and the works to which the materials are to be applied, and the Contractor will be responsible for the due employment of the same accordingly; and at least forty-eight hours previous to the making-up of the monthly certificates, he will deliver a correct return as to the due employment of such materials to the Company's Engineer, who will, if dissatisfied with the same, duly investigate into the matter, and, if he deems it necessary, will deduct from the certificate the value of any material not satisfactorily accounted for.*

It is to be distinctly understood, that no part of the Company's materials are to be made use of in any way whatever in the Contractor's plant, but that all such plant, as hereinbefore mentioned, is to be provided by the Contractor under the contract.

The Company's timber will not be allowed to lie in pond, and the Contractor will provide, under the Contract and at his own cost, sufficient sheds for the storing of all iron or other materials requiring protection from the weather.

For tunnel-work, the Contractor will provide a transit instrument.

The Contractor must carry on the works with sufficient plant, materials, and number of men for their due progress and the dispatch requisite for completing them in time. In case of his failing in this respect (but without prejudice to above-mentioned conditions), or to conduct the works to the satisfaction of the Company's Engineer, it shall be in the power of the said Engineer, after giving to the Contractor 21 days' notice to that effect, to suspend him from their further execution, and to seize upon and use all his plant and materials which may be upon the works, and to employ other parties thereon; and such plant and materials shall be valued by the Company's Engineer, and credited to the Contractor at the amount of such valuation; and any additional expenses incurred by the Company, and consequent upon the completion of the works, shall be charged to the Contractor and his sureties, or deducted from any amount which may be due to him, or shall be recoverable by the Company as liquidated damages.

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* Clauses to the above effect are indispensably necessary for the protection of the Company's property as well as of the true interests of the Contractor. Unless adopted, it will be found that the materials for which the Company has paid a high price, and often in large quantities, are distributed about indiscriminately, as though under no one's charge; and that Contractor's earth-waggons and wheelbarrows, wheeling-planks and scaffolding, temporary bridges, stream-crossings, and centerings, carpenters', blacksmiths', and numerous other sheds, all of which come under the clause by which the Contractor is to provide all plant, &c. (and which is inserted in every Contract for public works which the writer has ever seen), are made up out of timber and iron paid for by the Company, and intended for very different purposes.

In the construction of all the works necessary to the execution of this Contract, the Contractor will strictly conform to all the laws and regulations of the realm in force, and in any way bearing upon the execution of the railway works.

The Contractor, whenever required, will furnish the Company's Engineer with a statement of the arrangements he proposes to adopt in regard to all the works; and in case the Company's Engineer shall consider any alteration in the same desirable, the Contractor will conform thereto.

The Contractor guarantees the Company against any extra claims beyond the lump sum agreed to, under any circumstances whatever, and takes upon himself the construction of the whole of the works, and also all risks of failure of any of the works.

It is distinctly understood, that the drawings of specimens or types of works accompanying this Specification, are only intended to show generally the description of work contemplated; that they are subject to modification in any way the Company's Engineer may deem requisite.

The Company will have the power of using the permanent way, and any locomotive on the works, free of charge, on the Company's Engineer giving twenty-four hours' notice thereof, in writing, to the Contractor.

[A clause must here follow, enumerating the stations with platforms and road-approaches, and giving a sum for their complete construction; a sum of —— for sheds and workshops; a sum of —— for stores and warehouses, &c., containing — cubic feet in the clear; the whole of the buildings being finished in every sense, and complete, with cranes, weighing-machines, weights and scales, desks, counters, seats, and left in complete and efficient condition, in all respects, for traffic and occupation; and the sum of —— for —— yards lineal of timbers, jetty, or jetties, forty feet wide, and —— lineal yards of timber quay, including all filling, cranes, mooring-posts, and all matters to render them complete; a sum of —— for masonry in harbour-works; a sum of —— for pontoons and landing-jetties, &c. &c., so as to draw a distinction between such works and the line works, and so as to have distinct sums appropriated to various other works, and certain quantities in them. By these means the Engineer will be able to make alterations, additions, or deductions, from one work to another, according as information is obtained as to circumstances relating to traffic, and as to the wants and necessities as they are most likely to become developed at various points, and for different purposes. In a land so totally strange, where at first we know positively nothing of the wants and trading habits of the people, where a large amount of conflicting interests are deeply engaged with different views, this subject of traffic, and of the direction it will take, will be found to be one requiring most anxious and searching investigation.

The above Specification is given as a remembrancer for most of the conditions generally, that may arise on foreign lines of railway. Many of the clauses may appear strict, but the writer's experience has taught him that the Specification for these works can scarcely be too full or explicit, in order to prevent misunderstandings, and that it is very requisite to see it carried out in its integrity, and to prevent any evasion, which often may ruin a Company's works.

In adopting the permanent way with rail and *chair*, the author has merely done so to conform with the more general practice, and not because he deems it to be the best. Under the head of Permanent Way, some further observations will be made on the subject, in one of the following chapters, where to the best of his knowledge, the principle of forming the permanent way which is at present the most approved, and which must doubtless form a sound road liable to little if any derangement, will be pointed out.

CHAPTER VII.

RAINFALL—STREAMS AND TORRENTS—CULVERTS AND CONTINGENT WORKS.

THE extreme heat and the other characteristics of a warm climate, sometimes by themselves, or in combination with some of the remarkable physical features often occurring in high thermometric regions, constitute prominent conditions as regards the design and construction of some of the works of art on railways in the East. When these great heats prevail during by far the greater portion of the year, watercourses must with the common process of nature be flooded periodically, more particularly in mountainous countries and in the neighbourhood of the sea. Evaporation is very great, and a large portion of vapour is collected by long ranges of mountains, often two and three thousand feet high, springing suddenly out of the face of the earth in a land of volcanic formation. Unless drifted away by some particular atmospheric currents, it returns in a long and heavy rainfall soon after the cool season of the year sets in.

Throughout the regions of the plains and along the spurs at the bases of the mountains, there is frequently no rain for eight or nine months in the year. Vegetation is largely supported by the heavy dews of the summer nights, in addition to the system of irrigation pursued, either by tapping streams which draw their supplies from springs, and more usually by means of wells, from which the water is drawn up by very primitive wheels, mostly connected with small tanks.

Generally, during this season of the year, streams and rivulets, with few exceptions, gradually dry up, until the only remains of watercourses are mere threads of water, clear as crystal, circulating along their beds throughout the height of summer. Even many considerable rivers are in the same conditions, and where large and deep bodies of water may be flowing throughout the winter, only a few inches in depth impede the crossing of the channel during the dry season of the year.

It is sufficiently evident that a grave error is committed when the dimensions and works of bridges and culverts are determined by the appearances then assumed as regards the flow of water. Deep banks, large stones, and often boulders of rock in the vicinity of mountains, as well as rocky beds, furrowed into deep holes, sufficiently proclaim that a very different state of things must rule at some periods of the year; and this alteration, usually of a formidable character, generally sets in a little before the close of the year. Shortly after this period, and where the streams take their course through an undulating country, there are as many feet in depth of water as there were inches during the height of summer; and large bodies are often precipitately flowing along channels which but a month before were completely dry, this being the case more particularly, of course, during those periods of incessant and heavy rains which often last for many days and nights together.

In exceptionally wet seasons, and these generally occur at about every four or five years, the rain often lasts for six weeks and two months, and in the mountains the fall of snow is proportionately heavy. We may then calculate on a fall of between seventy and eighty inches. During one wet season the writer has known of a fall of upwards of ten inches in one night. At such times large masses of water usurp the place of the dry land, and where during the hot season the ground has been hard and dry, with barely a few withered vestiges of vegetation, marshes eight and ten feet deep invade large districts, and do not disappear until some months after. Much, however, of this is due to the want of proper drainage and to the condition of rivers which have become largely silted up at their outfalls.

As regards engineering works—such as earthworks, river-bridges and culverts, foundations in the course of construction—the approach of the circumstances which must arise under these conditions is of the greatest importance. Unless all waterways are sufficient, all piers constructed with the best materials and in the strongest possible manner, earthworks near watercourses well finished, battered, drained, and protected; unless due attention has been given to all wing-walls, and everything about the works is in a suitable condition,—serious damages are sure to ensue under the heavy pressure caused by the torrents which then flow in every direction. It may, therefore, be as well to mention the atmospherical appearances which announce the advent of a wet season, which may almost always be foretold for a month and six weeks beforehand. Dull-looking clouds, in larger masses than usual, arise here and there in the horizon and behind the mountains, and multiply in various quarters of the heavens; they spread horizontally and towards the zenith, slowly and gradually, until in the course of two or three weeks the entire canopy of the heavens becomes obscured. They darken and shroud the mountain scenery until nothing above the horizon is visible but this grey leaden hue. The longer nature is in operating this change in the atmosphere, the heavier the rain may be expected to be. During the whole of this time perhaps but very little rain falls, at least in the lowlands, for days after the complete obscuring of the sky into one unbroken mass of cloud; but at last the floodgates open, and after a very few brief intervals of cessation, the rain pours down at last heavily and incessantly, forming torrents which tear down everything before them unless judicious provisions have been made to lead the waters off. It is remarkable also that these very wet seasons are often preceded by a summer somewhat stormy and showery towards the mountains.

The inhabitants are perfectly acquainted with the meaning of all these tokens in the atmosphere, and very readily give and even press their advice upon those strangers it may concern, to take preparatory measures to avoid disastrous results. It is not a little surprising that men are to be found with such insurmountable stubbornness as to neglect all warning, refuse all belief, and treat every advice with an indifference almost amounting to contempt, for which the "*morgue Britannique*" amongst some Englishmen is better known than admired. It is needless to observe that unless "the ship be trimmed for the storm," bridges are washed away, culverts choked up and destroyed, and insufficient slopes of embankments ripped up, so that they often settle down for many feet. The permanent way is destroyed for miles, and to such an extent that it often takes months to restore, to say nothing of the cost of getting and leading an enormous quantity of ballast for this purpose.

The writer has already observed, that during one of these wet seasons he had known of a ten-inch depth of rainfall in the course of one night, and he has every reason to believe that, although this is not a common occurrence, it may still be expected to happen often enough to require provision being made against it. He has even safe grounds for believing that at times the rain is still heavier, from observations made on a river which, at the particular time here referred to, had not its storm-channel quite full. He was credibly informed that this river sometimes overflowed its deep banks to a considerable extent, and he found means of tracing the circumstance so as to satisfy himself that such was the case.

If we now take a case of two or three embankments crossing a valley which may form part of the area of watershed down from mountains steep and lofty, some seven or eight hundred feet high, and sometimes two or three thousand, a very short calculation will show the immense amount of water which has to be carried away through the culverts and bridges in the embankments; nor is it the quantity alone which has to be considered, and we must not lose sight of the great velocity with which these torrents flow towards the works crossing their path.

In Europe we almost always find at some short distance below or above a stream to be crossed, some arch by which we may regulate the dimensions of the new work we have to design; or we readily find some other traces to enable us to judge of the requirements of the new case before us: but in those countries to which we now allude, the finding of any former crossings would only form the exception to the general rule, and we must consequently often form our conclusions as to the dimensions required, approximately by some few rough calculations, being careful in deciding that the error shall be on the safe side.

Thus a ten-inch fall for twelve hours per mile square will give 530 cubic yards of water to carry off per minute, and this quantity running with great velocity, our wing-walls and foundations will require as much attention as the dimensions and other provisions of the bridge or culvert itself.

Some further idea may be formed of the extent to which these floods reach, when the writer mentions the case of a river which throughout the summer he could cross without finding the water ankle high. The channel was ninety feet wide, and during the flood it was full to a depth of seventeen feet.

He has ventured to press this subject upon the reader's notice, from the conviction that next to actual river-bridges, these culverts *on some parts* of the line, constitute the most expensive works of art, the road-bridges generally, for reasons assigned elsewhere, being a comparatively inconsiderable source of expense.

The subject of culverts for the countries now alluded to, may be placed under four different divisions, established certainly only by an arbitrary opinion, but which division will at any rate enable the writer to explain the views which his experience has led him to entertain. These are as follows:—

1st. Mountain streams.

2nd. Streams crossing the site of embankments which are to traverse valleys forming part of the area of watershed of mountain ranges, and near their bases.

3rd. Streams in lowland plains.

4th. Streams traversing table-lands of no great altitude or extent.

To these may be added some special cases which will occasionally occur in any of the above divisions, as where streams or occasional torrents cross the site of the railway at about the intended level of rails, when syphons of wrought or cast iron, or timber, or culverts with sumps may be used.

In the crossing of torrents and streams under the first division, such as we meet when going round and through the spurs and lesser valleys at the base of a lofty chain of mountains, the principal features we have to consider, next to the volume of water, are generally the rapid fall of the ground, and the consequent great velocity and the depth of the stream as soon as the floods set in. In its natural state—that is, before the construction of the railway embankments—the watercourse is overflowed as soon as the heavy rains set in, to an extent corresponding to the area of watershed or collecting ground, and the water has a wide range for passing off the land; but the construction of the embankment totally alters the state of things, and the torrent will be confined to the culvert that has to be built for its passage; and in consequence of the steep fall of the ground and the depth of water, the upper end of the culvert will be choked up unless made of very large dimensions, or unless some less costly provision be introduced into its mode of construction.

It will also be very evident, that in such a case the wings of the embankments must be so built as to protect the foot of the embankments, and other precautions taken to prevent these earthworks from being seriously injured by the great quantity of water pouring down with great velocity for a period of perhaps two or three months.

On the other hand, some of the sectional areas of the culverts for these mountain torrents do not require to be very large, from the limited extent of the area from which the water flows off, and which generally may be easily ascertained with sufficient accuracy for the purpose required. Were it not for the great rapidity with which the water is carried away, ordinary barrel drains would be sufficient. It is also to be remembered, that in many cases considerable quantities of vegetation, torn up by the violence of the storm, is often another subject deserving consideration, and which demands *width* rather than height in the culvert; but an examination of the ground above the site of the embankment will soon determine this point.

Every engineer is perfectly aware of the necessity of sufficient waterway through every embankment; and even in the mountain districts of Europe, where the rainfall is very much less than in southern latitudes, the subject requires attention, in order that culverts may be built of suitable dimensions, in order to ensure economy with due efficiency; but where the amount of rainfall is so large over a period of time comparatively so short, the necessity for considerable attention becomes perfectly evident, and if not a subject for what we may term study, it is one nevertheless requiring proper investigation. In every case earthworks always form important portions of a railway. Where they are not always in good order, there can be no sound permanent way; and if they are liable to be ripped up at the mouths of culverts, constant settlements are certain to ensue.

With exceptions, it will be found that, in the first two of the above divisions, the culverts and small bridges for streams and rivulets will have to be of large openings, that is, when compared to those we should assign to the like dimensions of watercourses in those portions of Europe where most of us obtain our first railway experience: and the only way to avoid all extremes, is to examine the bed of the stream for some distance up the current, and to get an approximate idea of the area of collecting ground. The greater necessity exists for combining strict economy with efficiency on this subject, inasmuch as it is a description of work which in these countries is generally more or less expensive, on account of the distance which material has sometimes to be carried, the insufficient means of transport on many occasions, and the difficulty there is to obtain that sound quality of archwork, in the roof as well as in the invert, which a culvert requires, more particularly under a heavy embankment.

It would not be very difficult to show, that in the one case some twenty-five per cent. may be economized by proper attention to this subject, whilst on the other a continual injury to the earthworks and permanent way will ensue from neglecting it, whereby the working expenses of the line are yearly greater than they should be, until an expensive remedy is applied.

During the dry season, after the strong and rapid vegetation of early summer in these fine climates, it will be found that very often barely a trace remains along the banks of the watercourse, to denote the flood-height reached by the large volume of water that has passed over, or the quantity of *débris* which it has carried along with it, though probably at some spot a short distance lower down, where they have been arrested by some accident in the ground altering the regimen of the stream, they will be found sufficiently large and numerous to attest the amount of consideration required.

The writer thinks it the more requisite that he should observe upon these facts, because they are such as will not at first command sufficient attention from the stranger unaccustomed to the conditions of the streams in these climates, or until he has seen their effects, or gathered local information; and because he has noticed on several occasions that very large culverts have been constructed, through which a greater depth of water than two feet never flowed, whilst in other instances culverts of three and six feet opening, under deep embankments, were choked up and destroyed from the insufficiency of such dimensions, and where water-ways of twice the size were required. These few important facts are mentioned merely to explain why so much more attention must be given in those climates to works which are generally of minor importance in countries of lower temperature, though there are cases, even with us, where the subject of sufficient water-way in culverts requires more than ordinary attention.

One of the most dangerous circumstances that can occur to culverts or to bridges in embankments, is the access of water at the back of the wing-walls, and to green work it must be of course particularly pernicious; the depth attained by the water in times of floods, and not only the depth, but the impetuosity with which it approaches the works after having overflowed the banks of the ordinary channel, render some special provision very requisite in many cases: this will often consist in the prolongation, in the direction of the banks of the watercourse, of one or both of the wing-walls, so as to form on one side or both, a bell-mouth to receive the flood waters, and thus prevent them from reaching the foot of the embankment. These prolongations will often have to be built up into the banks of the stream: some half-dozen cubic yards of rough masonry thus employed will often save much damage.

Where the natural angle of crossing of a stream is much altered, in order to diminish the 'skew length of a culvert, precautions of this description will be found very necessary.

In order to diminish the length of a culvert, and to avoid 'skew work, it is not an uncommon occurrence to alter the crossing of a stream from 'skew to square, and so long as there is only the ordinary quantity of water flowing, this is not a matter of any very great consequence; but as soon as we have four or five feet of water, and often more, where previously there were but a few inches, all the conditions are entirely altered: the stream approaches at a high velocity, and is, under an ordinary system of construction, suddenly checked against the angle formed by one of the abutments and wing-walls, and a regurgitation violent in proportion to the velocity of the stream is the consequence; and when this lasts incessantly for weeks together, the masonry or brickwork must necessarily be severely tried. On side-lying ground the angle of fall of the stream is also often very much altered, and the level course of the invert, together with the impinging of the water on the masonry at its entrance into the culvert, produce a very violent action from the stream. The writer's experience has led him to adopt the introduction of steps in the culvert with walls or sumps, so as to give greater facilities for the stream to escape at its outlet. Under any circumstances, the quantity of work is not increased, and in most cases of torrents, it will be found that by the adoption of this system, the dimensions of culverts may be made less than they otherwise must be. It will also be necessary to be very careful in the manner of constructing the new channel from the outlet of the culvert to the stream.

The proper connexion of wing-walls with the abutments by obtaining a real bond, is another protection which in these cases is more especially required: this bond must always be imperfect, or difficult to obtain, where in a battering wall the courses are perpendicular to the face of the batter whilst the courses of the abutment are horizontal. It will be found an improvement securing better bond, to get the batter of the wing-walls, by stepping and building the courses horizontal, as shown in some of the drawings at the end of this volume.

The culverts under the second division are usually the most expensive, and require the most study and attention: the streams for the passage of which they are built, carry off by far the largest body of water, and it is generally over these that railway embankments traverse the more important valleys which have a large area of watershed, and which are secondary only to the main valleys drained directly by the rivers to which these streams lead. Unless the culverts, under this division particularly, are sufficient in size, and have all their contingent works properly designed and constructed, damage from the floods must ensue at every rainy season, however often it may occur, giving rise to a constant source of expense in repairing culverts and earthworks, large quantities of which may be washed away; in procuring proportionate quantities of ballast for and in restoring and repairing the permanent way, which can never be even in tolerable order when the condition of the earthworks is not thoroughly stable and good, and slips in which are always difficult and expensive to repair. By all of these a Company's working expenses are very considerably increased, whether they put it on one shoulder or the other, by setting off to revenue or capital, besides giving rise to that fertile source of danger, abrupt settlements, which occasion accidents, great damage to all rolling stock, delay and expenses more than enough during the construction of works, and are of still graver importance after the line is open to public traffic.

The streams in the lowland flat plains do not generally require the same amount of investigation as those above mentioned; the sectional area of the watercourse is usually distinctly to be traced, but it is requisite to ascertain the heights to which these plains may be flooded, both as regards the culverts and the earthworks.

The streams under the fourth division, traversing table-lands of no great extent, and which are not accessible to the streams fed by the waters from the mountains, are those requiring the smallest culverts; but long cuttings through these table-lands require the most ample side drains, and often special constructions, but of a light character, to carry off from the mouth of the cutting the large volume of water often brought down.

The last condition as to culverts which the writer considers it necessary to mention, is the following: in traversing long, flat valleys, a very slight rate of declivity will be observable until the lowest point is attained, when the land will rise again at perhaps the same low angle of inclination; at this point there will be a watercourse in seasons of floods, though not the slightest trace of a channel is to be noticed during the summer, and only a very slight scooping out of the land right and left of the line is to be observed, extending *sometimes* as far as the eye can reach. Valleys of this description are usually crossed by very low embankments, and the culverts will require to be formed of several openings according to the area of watershed, or possibly a flat-topped wide culvert will have to be formed.

CHAPTER VIII.

RIVER-BRIDGES—ROAD-BRIDGES.

THE observations which have been made on the flow of water during seasons of floods through culverts, and on the design and construction of these minor works, will bear with at least as much force on the subject of river-bridges, more particularly when the channels of the rivers are enclosed by deep and precipitous banks, as they are so often met with in the vicinity of mountains and steep lofty hills. Generally in these formations, the sectional area of the channel of the river will be more or less rectangular, the slopes of the banks assuming a flatter inclination as the stream makes its way towards more level country.

It has already been observed that, in many instances, where these rivers do not carry more than a foot deep of water throughout the summer, a depth of from fifteen to twenty feet occurs at seasons of heavy floods; and where the channels are in any way confined, the impetus of the flow of water is so great that all obstructions other than those of the greatest strength are irresistibly swept away. It will be scarcely necessary to remark, that this periodical regimen exerts a powerful influence on the beds of such rivers: this is sufficiently evinced in most instances by the deep holes and furrows torn in the beds and sides of the channels, and by the large banks of gravel and sand which are shifted. It will be sufficiently evident that the bridges by which such rivers are to be crossed require particular attention in their design and throughout their construction.

In the neighbourhood of large towns generally, even in those countries to which reference is now made, the conditions as regards labour and materials will not vary so very much from those which the Engineer meets everywhere on the subject of similar constructions; but as the works become further distant from great centres of population, all these conditions become materially affected, and more or less according to the character of the roads, the distance materials have to be carried, the quality of labour to be obtained, the dispositions made to obtain the best results therefrom, and the practicability of bringing on to the site of the works many of the appliances by which labour is economized.

Whilst we remain in stone districts, and we can obtain stone from quarries near the works, many of our difficulties are reduced to a minimum, if any measures have been taken to train the native masons; but as soon as quarries become distant, the carriage becomes proportionately expensive on account of the roads, and more or less so accordingly as commonly reasonable provisions have been adopted or neglected: so long as the building-materials are at hand, however, the cheap rate of the labour required for stone-dressing and setting, at least in all plain work, will enable us to do much of the construction very economically, more particularly when it is considered that, in many cases, the stone is obtained free of cost. When it has been ascertained that stone is not to be obtained in the locality where any large quantity of masonry will have to be constructed, the question of brick-making becomes one of great importance, which should be investigated at the earliest possible stage of the works, and measures taken accordingly. On this subject, a few observations will be made hereafter: it is one which will often prove of the greatest importance, as may indeed be readily perceived from the remarks already made as to the resources of countries placed under such conditions. As regards the bridges over rivers, such as are above mentioned, much of the work will be found of a very expensive character, if we adopt the style of work which would be usually applied in Europe; that is, piers, and arches of moderate span.

The velocity of the flood-waters, their great depth, and the quantity of heavy materials often brought down with them, necessitate, in the first place, openings large enough to ensure their free passage; in the next place, the piers must be carefully designed, and set out parallel with the line of the current, which will involve 'skew-work generally: the piers must occupy as little space as possible, which necessitates their being constructed of the best description of Ashlar masonry, with thoroughly efficient cut-water buttresses, to ensure as substantial a hold as can be obtained on the foundations, and offer as much resistance as possible to the power of the stream, and interfere as little as possible with the volume of water. The foundations will generally require to be deep, and unless we have a very solid natural bed in the channel, we shall generally require the addition of sheet-piling, or some other adequate means, to protect the foundations from scour.

With regard to all the above features of construction, it will be found that the Ashlar masonry required to produce even plain substantial work, which must be introduced into such work, both as regards stone-dressing and setting, will be very expensive: as regards the latter, unless the workmen have had some training, scarcely a stone can be set without superintendence, and they have had so very little experience of the former, more particularly of such work as must be bestowed on the beds, joints, and backs of Ashlar masonry, in piers such as are now alluded to, that an equal amount of supervision is required: this by no means arises from want of intelligence, but merely because they have never, in most cases, seen the kind of work before. The same may be observed of any attempts to construct an arch, except where the spans are small; even in brickwork and on a square crossing, the work having often to be taken up two or three times before anything fit for use can be obtained. The foundations required for such bridges will also be more expensive generally than they would be in Europe: to all these sources of expenditure, we have to add the sheet-piling, or some such protection to the foundations as will be found necessary in very many instances.

It will be seen from these observations, that river-crossings of this character must be expensive, and take considerable time in constructing, where the system of piers and moderate sized arches is adopted; and the writer believes that, in most of such cases, economy would be effected, time saved, and more satisfactory results obtained, by adopting wider spans, and flat-top bridges.

When the river is not confined to a channel which may be termed narrow, when we take into consideration the immense volume of water brought down, and where, from the gradual slope of the surface, the flood-waters very soon overstep the banks and spread out in a large sheet, circumstances, as regards the regimen of the flow, are entirely different. There may be a great increase in the volume and depth of water, and comparatively little in the velocity: a system of piers and arches may here be adopted, provided that the spans are of sufficient width to allow free passage to the *débris* brought down by the floods; but in these cases, even more than in the former, it will often be found requisite to sink to a considerable depth before a secure natural foundation is reached, which we shall have to do by excavating and throwing in concrete, or by piling. To effect the latter, we must get a pile-driving engine on to the ground, and the carriage of the ram alone would be, generally, a serious affair in such countries.

This last style of crossing is, however, much more within the ordinary range of practice, and the more usual modes of crossing may be more readily applied than in the case above mentioned. As a general rule, however, if he may venture to say so much, the writer believes that, on account of the reasons above assigned, girder-crossings will be found the most economical and efficient: he also believes that very great spans should be avoided as sedulously as the small; from about fifty to sixty feet will generally be found to leave ample width of opening. Great spans involve more or less the necessity of heavy plates, for which special modes of carriage would have to be introduced; the term special, however, being applied as regards the means of carriage adopted in the country or that may be applied to the roads. So long as we can make use of these, no great extra expense will be involved, but otherwise, this important condition in construction will be materially altered.

It will be understood that the writer does not allude here to lofty viaducts, which would necessitate long and deep girders: he does not by any means feel satisfied that, generally speaking, in countries which are placed in the circumstances and conditions here referred to, such structures will be introduced for some time to come, unless indeed the Governments are prepared to aid the Companies in a financial point of view. Where such constructions are needed, almost the whole of the skilled labour would have to be imported from Europe. When far from towns, special establishments would have to be made for the shelter of the men, or they would very shortly be lost; workshops of no trifling magnitude must be erected, and this perhaps in a mountain district where a few scattered huts are the only signs of human habitations;—to all of which would have to be added the existence of mere earth-roads, or steep and rocky acclivities skirting the mountain sides, on which heavy materials must be carried, and the entire absence of vehicles on which to transport them. We all are perfectly aware that greater difficulties than even these are to be overcome, but it is only at great expense.

The instances of river-crossings to which allusion has been more particularly made as yet, are for widths of above (say) forty or fifty feet up to those of perhaps one hundred and fifty feet, or thereabouts. There is one more to which reference has to be made. This is a river-crossing perhaps of twenty or thirty feet, and on the 'skew, and where in flood seasons large bodies of water are carried down the channel with great impetuosity. When these are first hastily glanced at in summer with a mere thread of water making its way along the bed, it is often hastily determined, without examining the conditions of banks and bed, to alter the course of the stream into a square crossing, in order to obtain less span and easier work and shorter wing-walls. Such alteration often occasions the destruction of the bridge as soon as the floods have fairly set in, unless special provisions have been made for its protection from the attack of the waters which, in heavy and impetuous masses, fall on one or the other of the abutments, and keep up the work of destruction until the masonry is pulled out as exactly as though it had been cut out by a good workman. In most of these 'skew crossings it will be found a better plan to adopt a flat girder, and leave the course of the stream unaltered.

In very many instances of railway construction, such as that now referred to, where the capital has to be economized with the greatest care for the numerous reasons which have been referred to in these pages, there can scarcely be a doubt that the upper works of such river-crossings might, at least temporarily, be constructed of timber. It has been done very considerably in every country in Europe, as well as very largely in America; and in the East, where so much has to be done in order to bring railways into actual operation on the face of the country, good timber crossings might be most beneficially introduced, not meaning, of course, Contractor's temporary bridges merely, but such as we have so many numerous examples of both in France and England, as well as elsewhere.

The Concession granted by the Ottoman Government for the Smyrna and Aïdin Railway, and which merely has been given in this volume as an example, leaves the Company quite free as to its mode of construction, and if in all such cases, efficient economy is studied, it will be found that the amount of capital allowed is fully sufficient to introduce the collateral assistance to the railway to which the Concession so often refers, and without which, a line of railway by itself will effect but little for the country, and be unproductive to the shareholders: that is to say, that roads and branches, in conjunction with the rails, it must be repeated, are indispensable to success; and to effect this, recourse must be had to all possible means of economizing capital.

It is always much more gratifying to the Engineer to construct an arch, or iron bridge, instead of a timber one, and he will never select the latter material from choice, knowing very well that it involves renewal at some future time; but we have so many instances in all great railway countries, of heavy works economically accomplished through the intervention of timber bridges and viaducts, which but for such assistance would never have been commenced from want of funds, that there can be no hesitation to recommend the adoption of similar means, for countries which are as yet completely in a state of infancy and probation for all works of public utility. To prevent misunderstanding, however, the writer must repeat that he is not speaking in favour of a "Contractor's bridge," sufficient merely for the construction of works, but of such timber-work as will at any rate last some quarter of a century, during which period means may be gathered to obtain a superior kind of construction. As far as his experience entitles him to offer an opinion, he believes that the masonry required for abutments, ordinary piers, and wing-walls, may be constructed, as far as labour is concerned, for full twenty per cent. less than in France or England, unless some very unusual circumstances intervene; whilst it will be found that the description of labour required in the construction of Ashlar piers, and for arch work, will generally cost from thirty to fifty per cent. more, and in many circumstances this might be exceeded: where, in addition to such cost of labour, it is necessary to add that of carriage of large blocks of stone from any distance, it will at once be seen that it is very desirable to consider seriously as to the kind of construction to be adopted for all crossings of any consequence.

Enough, probably, has now been said upon this subject to make it evident that, even in ordinary circumstances, all river-crossings in such countries require special study as to locality, before any one style of construction is hastily adopted. All the conditions under which we have to work are such, also, that the subject should be carefully studied at the earliest opportunity, so that the plans may be well matured before the actual commencement of such works, and to give time for making provisions necessary to particular circumstances: this will always be one of the surest sources of economy, and it is surprising how much money may be saved by such simple means.

ROAD-BRIDGES.

A very great deal of difference may arise in the character of bridges for road-crossings. In the close proximity of, or through important towns, they must generally have the dimensions and appearance of similar constructions in European towns; but such crossings will be of very rare occurrence. As soon as we have reached a distance of some two or three miles from large centres of population, a road-bridge becomes quite an exceptional structure, and ten or twelve miles may often be run over without meeting with the necessity for building one. Generally, level-crossings may be made, which, in character, will resemble those adopted for private roads in Europe, reference not being made at present to roads immediately opening into large towns. Where a road, at any distance from such a situation, has to be carried over a railway, a most simple timber construction is all that will be required; and it must, indeed, be made very narrow, if it is not wider than the road it has to carry is at each end; even on roads of considerable importance, from twelve to eighteen feet will be found very ample between parapets or abutments, and it will be but very seldom that the latter dimension will be required. The Government Specification of Conditions gives 9·8 as a minimum, and 24·6 as the maximum required width: these bridges are, however, of such rare occurrence, that they become quite a matter of minor importance when taken in connexion with the whole of the line works.

Of occupation works nothing need be said, as they will only consist of a field-gate here and there.

CHAPTER IX.

EARTHWORKS AND PERMANENT WAY.

However excellent and plentiful the materials with which the permanent way may be constructed, and however good the workmanship in laying them, a good road can never be obtained, unless the earthworks are substantially executed, permanently established, and well drained; and the cost of maintenance, particularly for some years immediately after the opening of the line, depends, to a considerable extent, on the care with which the earthworks have been made; when these have been badly executed, water will get in by some means, and there is at once an end to soundness in the permanent way. These rules will hold good wherever there is railway-making, and will be all the more valid in countries liable to heavy periodical rainfalls.

It is not necessary that the formation be very wide, or that the slopes should be very flat, but it is most important that the formation be kept entirely free from water. Before any ballast is laid down, the cuttings should be cleanly and evenly bottomed out, and the side-drains must be sufficient to carry off all storm-waters, and prevent any portion of the ballast lying in water: it is important that the slopes be very uniformly battered and thoroughly out of winding; any defects in these respects are very soon found out by heavy rains, and magnified yearly as the rainy season sets in. The slopes should be kept thoroughly free from water, whether arising from springs or soaks, as these will very largely increase as soon as the wet weather comes on; where any of these make their appearance, measures should at once be adopted for carrying the water off, either by a pitched side-drain down the side of the slope, or by sinking a well communicating laterally with the side-drains, and filling the well with dry materials, or by the numerous methods adopted under similar conditions.

In cuttings of considerable length it is necessary that the side-drains be capacious. During the rainy season, a large quantity of water is intercepted by one, if not both, of the crests of the cutting, and can only escape at either end; unless the side-drains are of sufficient size to carry off the water rapidly, the lower part of the ballast is constantly in a wet state, the bottom of the cutting gets muddy, and the ballast sinks into it; the mud rises upwards and chokes up the drainage; it washes out from under the ballast, and accumulates in the drains, which thus become more deficient than before the rains first set in. During a wet season, in long cuttings, where this very necessary provision has been neglected, the mere pressure of the foot upon any of the sleepers will cause the mud to ooze out from underneath; and in many cases, the sinking of the ballast into the bottom of the cutting has been so great, that the sleepers have been left hanging in mid-air, carried by the rail, instead of supporting it; damage by this and other neglects of earthworks has become so extensive, that orders have been given to prevent trains travelling at a greater speed than 10 miles an hour. In these hot climates, under such circumstances, the ballast has, in a few weeks after the return of the dry weather, caked almost as hard as stone, and a kind of pounding of the rails goes on as the trains pass over, which is most destructive to the rolling-stock as well as to all the permanent-way materials, and dust, instead of mud, may then be seen issuing from beneath every sleeper.

In making embankments, it is very requisite that they should be formed at once to their full width, height (allowing carefully as much as possible for settlement), and to the full batters. When made of insufficient width at the base, the embankments are sure to settle as soon as the floods come on, and this pretty much in proportion to the depth of rainfall and the deficiency in the width of base: this settlement seldom occurs gradually and regularly, but by slips, which rip up the slopes and cause a damage which is hardly ever completely repaired. In some side-lying grounds these slips are often very considerable.

When embankments are thus formed deficient at formation of width, the work has afterwards to be done by side-filling, but the earth, more particularly that which is of a stiff or clayey nature, on which the filling is tipped, has become baked so hard under the excessive heat of the summer's sun, that no adhesion whatever takes place between the two: they remain most distinctly separate, the rains of the first wet season find out the line of separation, and slips ensue.

We are often so circumstanced in those countries, that there is necessity to get materials forward as rapidly as possible by rail, and the embankments are temporarily formed of a minimum width of formation, in order to accomplish this as speedily as may be, always under a promise, of course, that the deficiency will be properly made good immediately the object desired is effected.

Thus a considerable quantity of side-filling has often to be done afterwards, and unless precautions are taken, the very evils just mentioned are certain to occur. The only chance there is of avoiding future evils from heavy falls of rain, is to trench the surface of the slope parallel to the direction of the line; of course this entails an expense, but it is one which the Contractor should not hesitate to incur, since he ensures a considerable economy in getting his materials forward by the cheapest means: unless, however, all this is arranged beforehand, and amply sufficient means retained in hand to meet all circumstances and contingencies, it will be found almost impossible to get the work properly done; much more even than in Europe generally, the quality of the permanent way depends on the substantial formation of embankments. When there are not sufficient means to pay for good, of course we must be satisfied with indifferent work; but hitherto this has certainly not been the case on railways in the Ottoman Empire.

Another circumstance of considerable importance as regards earthworks, and the permanent way of railways constructed abroad, under the conditions now more particularly referred to, is, that generally the Contractor makes use of the Company's permanent-way materials during the construction of the works, from which of course he derives considerable advantage, having no temporary material to provide for this purpose; and yet the difficulty of getting the cuttings even decently bottomed out, or anything like a formation made in the embankments, is a remarkable circumstance: the sure consequences are numerous holes, which during the wet season get filled for some two or three months with water under the ballast, and the result is a perpetual heaving and sinking of the permanent way, whatever may be the quality or size of the rails, sleepers, or fastenings, and whatever the depth, nature, or packing of the ballast. Such a road may be packed over and over again, with the most choice materials, and in the most perfect manner, but nothing will prevent water lodging in such places, and setting at defiance any amount of labour other than that of taking up the rails and ballast, and filling-in with earth, so as to make the formation what it should have been from the first, and which there should be no very great impracticability about where the capital most easily bears a charge of one shilling per lineal yard for formation.

The wide field generally allowed to the Engineer, in laying out the line for these foreign railways, enables him to select a route by which heavy works of almost every description may be avoided, if not for the whole of the way, at least for many considerable lengths. For some years to come, that is, until the country is more opened up, lines of railway on which, with partial exceptions, the works are of inconsiderable magnitude, must be the only ones which may fairly be constructed, unless roads are constructed for the purpose, and which roads will have to be commensurate with the importance of the works projected. The opportunities afforded of selecting an easy route will often enable the Engineer to traverse vast plains and contour valleys in such manner that all the earthworks may be reduced to a minimum: in doing this, the condition which will require the most attention will be the level attained by flood waters; this having been ascertained, the line may often be set out for miles in "surface forming," or in the shallowest of cuttings and embankments, so that the permanent way, a few culverts, and the fencing, will often be the only works for very considerable lengths.

Where, on account of the level attained by flood waters, it is found necessary to make deeper embankments through the plains or along the valleys, the excessively low price of the lands affords every opportunity for doing so at a cheap rate from side-cuttings, a description of earthworks which is, besides, particularly adapted to the native labour; sub-contractors gladly undertake this work at sixpence per cubic yard, and realize a very satisfactory profit; in many cases it may be done for much less.

In carrying on the work by side cutting, a little care is required to set out the tanks from which the earth is to be excavated, at a sufficient distance from the foot of the embankment, or when these tanks get filled with water, not only is there danger of a slip, but the near proximity of the water to the embankment facilitates the soaking of the embankment by capillary attraction, more particularly when the material is light peaty stuff, such as we find so often under similar circumstances.

Cuttings and earthworks generally in side-lying ground, standing at high angles of inclination, require more than ordinary study in countries which are subject to heavy periodical falls of rain. In some cases we may have to deal with a loose kind of rock, split about in every direction by volcanic action, dipping down to the bed of a stream and overlying some material to which water obtains access: as soon as any weight is taken off, as by excavation, a slip occurs; much the same may be said as to embankments similarly situated. In some cases a decomposed rock, much tilted up, may stand, without showing any very great signs of slipping, until excavations are commenced upon it, when matters will be entirely changed; but as natural slips may occur occasionally in these situations before breaking ground, it is easy to trace the possibility of anything of the kind.

Connected with earthworks is a subject which the writer ventures to think might prove a source of revenue to the Company, and one of vast improvement to the country traversed by the railway. In all hot climates, the subject of irrigation is one of the very first importance. In countries where there is scarcely any spring weather, and where the summer heats set in early in the year, all traces of the heavy preceding rainfalls very soon disappear: in most cases, streams that had shortly before been flooded, have their channels entirely dried up; and in districts where the watercourses are of this character, the want of easy means of irrigation is a great drawback to cultivation. The condition of the cattle during the height of summer, as contrasted with their appearance in the early part of the year, is sufficient evidence of this. In many cases where earthworks are made through valleys, it appears very possible that railway embankments should be made the foundation for the construction of reservoirs, as far as these may be made, with some additional work, in damming across the valley. Of course this could only be done in clayey or sound loamy districts; but in such cases there can be no doubt that with a very moderate additional expenditure, this could be effected, at a considerable profit to the Company directly, and moreover indirectly, by the great improvements of the lands. Of course to those who are accustomed to look upon a Railway Company merely as carriers, a condition to which they are restrained in European countries, the thought of their undertaking irrigation is novel at the least; but if the Concession above given be referred to, it will be observed that a much wider field than carriage of goods and passengers is open, and that they are invited to undertake much more. Those who know the country will not fail to perceive that irrigation must produce satisfactory results, both directly and indirectly, where, from the nature of the materials and form of the locality, reservoirs might be easily constructed.

It will be some time yet before steam-machinery can be introduced far inland, in countries completely destitute of roads fitted for the carriage of heavy materials. Where favourable conditions exist for the formation of collecting reservoirs on streams, they would soon ensure the establishment of various water-mills, which would very soon prove a prolific source of profit to a railway Company, by the vast improvements speedily introduced into the country; and where a Contractor's plant has once been brought on to the ground for the construction of railway earthworks, one-half of the battle is gained towards the formation of reservoirs, in any favourable locality, for the making of such works; after serving the purposes of the mills, the water could be used for irrigation. Without the railway, such works would be unproductive, from the want of means for carrying away produce; but combined, they would largely assist each other: instances to prove this would not be difficult to produce.

Although the writer advocates that, in order to ensure economy, some sacrifice should be made as regards works of art, provided they be such as will not interfere with substantial construction, he deems it always necessary that every provision should be made to obtain a sound permanent way.

There are now an immense number of systems and plans brought forward to secure this desirable object, all of which have more or less meritorious features to recommend them; and in selecting a few of these, he by no means wishes that the many various devices lately introduced by many most able men should be lost sight of; but the enumeration of all these, to do any justice to their great merits, would require a moderate-sized volume for this object alone.

The plan of using rails of the flat-footed or Contractor's pattern, laid on sleepers without the intervention of chairs, the joints being secured by fish-plates and the rails secured to the sleepers by heavy jagged spikes weighing about a pound each, appears likely to obtain some success, particularly on foreign lines, where timber sleepers are to be obtained economically. The permanent way was so laid on half-round cross-sleepers on the Smyrna and Aïdin Railway, but unfortunately the precaution of creosoting the sleepers, always adopted on first-class lines, was entirely neglected.

Where this plan is followed, the sleepers should always be of square sawn timber, the half-round being inadmissible, and for the following reasons: in order to obtain a sufficient bearing for the rail, the half-round sleeper requires to be cut to a considerable depth, which affords a lodgment for water; and every possible facility is thus afforded for the rail to batter into the softened wood; then sleepers are always much larger at one end than at the other, and sometimes even half as large again, which gives very unequal bearings for the two rails, and must ensure a rolling motion as the trains pass over. If the timber sleeper were flat, no notching would be required, and a much larger bearing surface would be obtained for the rail.

This system, however, might be adopted so as to economize very considerably both timber and ballast, and obtain a more satisfactory bearing on the ballast: instead of using sleepers from eight to nine feet long across the road, they might be used much shorter, and laid longitudinally. Timber sleepers of the size required could be obtained at a very moderate cost; they could be very easily carried, and readily handled; there would be good longitudinal drainage between the rails, where less ballast would be required; ample room might be left for cross-drainage; a less quantity of ballast would be required across the full width of the line, and there would be less packing; the only additional expense would be for light cross-tie rods, at about every eight feet, to keep the rails in gauge.

The necessity for a good depth of rail is now too well acknowledged to need any observation; and how far in the above system the absence of keys and of the jaws of chairs tends to any lateral twist in the web of the rail, remains yet to be ascertained: extra care should perhaps be given, in examining the fish-plates, nuts, and bolts. Wherever fish-plates are used, and there are now but few lines properly formed without them, they should be deep as possible, and they should truly fit the underside of the head and the upper side of the foot of the rail, without coming near to the web: the nuts should be of very full dimensions, to obtain as much friction as possible, and they should be at least flat on the side in contact with the plate, and even concave rather than convex. The underside of the head of the rail should not be pear-headed, nor absolutely so flat as some advocate; but as good a bearing as possible is indispensable; a careful examination should be made, to see that the holes punched in them are truly opposite on each pair of plates, and that no swellings have been produced by the punching. Where this description of bad workmanship occurs, the chances are that it will also be found in the punching of the rails; and this is likely to occasion a connexion between the fish-plates and the rails, which should be carefully avoided. The thread of the screws should be full and true, and of thorough good workmanship. Every attention is now being given to improve the quality of the permanent way, as regards material and workmanship, which will do as much to effect this object as new improvements.

Greave's pattern of cast-iron sleeper, or the pot system, has been very greatly used abroad. In Egypt the writer knows it has given great satisfaction, and similar accounts have been given of it on the Madras Railway. The pot-sleepers are said to have advantage over some of the other patterns as regards less liability to breakage, and their form renders them commodious for package. An objection of rigidity has been made against these sleepers, but the advantage which the pot-sleeper has of protecting the ballast beneath, should rather reduce this objection in its favour. This sleeper is in the form of a semi-spheroidal bowl with chairs, these being intermediate when required, and with fish-joint chairs to support the rails at the joints. These "pots" are about twenty-two inches in diameter, and placed about three feet from centre to centre. They are about seven inches from the base to the bottom of the rail, and the gauge is kept by wrought-iron tie-rods.

The following may be taken as an estimate for a single line of way in the East, materials delivered on the works.

Rails, 21 feet long, at 65 lbs. per lineal yard.

	£	s.	d.
102·2 tons at 9*l.* 10*s.*	1071	0	0
Cast-iron sleepers, 124 tons 5 cwt., at 6*l.* 10s.	814	0	0
Tie-bars, 22 tons, at 12*l.*	264	0	0
504 pairs of fish-plates, 5 tons 8 cwt., at 12*l.*	65	0	0
1 ton of bolts, at 20*l.*	20	0	0
Cotters and gibs, 15 cwt., at 1*l.* . . .	15	0	0
Keys	13	10	0
Including royalty . . .	£2262	10	0

The above is for the materials of a permanent way entirely of iron, excepting the keys, and which would probably last full 20 years.

With rails spiked down to sleepers, and fished, the estimate may be as under, for materials for a single line of way:—

113·14 tons of rails at 72 lbs. per lineal yard, at 9*l.* 10*s.* per ton	£1075
504 pairs of fish-plates, at 28 lbs. per pair, 6¾ tons, at 12*l.*	81
1 ton 3 cwt. of bolts and nuts for fishes, at 20 ozs., at 20*l.* per ton	23
3 tons 12 cwt. of jagged spikes, at 15*l.* . .	54
2012 sleepers, not creosoted, at 2*s.* 6*d.* . . .	251
	£1484

The timber sleepers, being uncreosoted, will have to be renewed every two or three years, if the permanent way is to be maintained in tolerable order, the decay of timber under ground in hot climates being very rapid, when no provisions are made for its preservation; and moreover, their ill condition in a year or eighteen months after their being laid down will cause the other materials to be much battered, if there is any traffic worth mentioning.

Superior sleepers creosoted would cost about 4*s.* 3*d.* each, or 428*l.* per mile, would wear for ten or twelve years, and would keep the permanent-way materials in as satisfactory condition as iron sleepers.

The system invented by Mr. J. Samuel has been adopted on very many railways. The chairs are cast so that one side forms a fish-plate, and a wrought-iron plate is bolted on the other side. The joint of the rails has in this case a direct support at the bottom.

Amongst the plates at the end of this work, the reader will find the last improvements introduced by the Permanent Way Company, and which will, no doubt, be very generally adopted, inasmuch as they appear to perfect the fish-plate system from which the permanent way of railways has already derived so much advantage.

CHAPTER X.

STATIONS.

Local knowledge and experience, either self-acquired or obtained through reliable channels—which must be studied with care and much discretion, the best sources of information being often self-interested, even unwittingly—are requisite to assist the most able judgment in determining on the site of an important station for a railway in communication with a large town. Although such a maxim, or truism as it may be termed, applies forcibly to every country, it is still more positively applicable to the East, in order that such station may be adapted not only to traffic exigencies when the line is first opened, but to the new state of things which the railway is intended to create. The efficiency of these establishments will depend greatly on the situation adopted. If unwisely chosen, it will do a greater injury to the development of traffic on the railway than such a condition would do even in Europe.

The experience acquired on European works will only be of use so far as it is combined with a perfect understanding of all the new conditions which, in some shape or other, will be met in hot climates, where railways are new undertakings, and where agriculture, commerce, and manufactures are undeveloped. The absence of good roads and of native means of transport renders the study of situation as regards stations, of vital importance to railway interests, and much more requisite than in countries of higher civilization, where so many ready means of collateral assistance are in existence for the furtherance of traffic.

With few exceptions, even in towns of first-class importance, the streets are in many places barely wide enough for the passage of a camel or other pack-loaded beast of burden; and generally as the centre of trade is approached, the streets become narrower, and so much so that the passage of two caravans side by side is impossible, in many places. When, under these circumstances, a terminal railway station is established a mile or two from such great centre of commerce, no economy in purchasing a vast area of land at a cheap rate will compensate for the most injurious drawback of distance from the active seat of business.

Even in countries where every possible convenience exists, in the shape of first-class roads, and of every description of waggon, cart, and carriage drawn by swift and powerful horses, the evils occasioned by distance of a station from a large centre of trade and commerce have only been remedied by enormous expenditure in carrying on the line of rails so as to bring the trains as near as possible to the seat of business, which almost always assumes a large extension, in consequence of the increased facilities, to the benefit of both commerce and the railway system. This is almost always the result, even although, previous to the extensions, such very easy means of ingress and egress existed, that it was often thought impossible to secure such increased facilities as would warrant the immense expenditure to be incurred.

It is easy to form a judgment of the present means for carrying goods through the towns of the East, simply from the fact that at least nine-tenths of the traffic is performed by the labours of porters only, who in important commercial towns swarm in long files along the narrow streets from morning till night, carrying enormous burdens throughout the day; other means are not to be attempted, for here and there in the old busy parts of the town, the streets in some places are not more than six or seven feet wide, and even less. To prevent misapprehension, however, on this point, it may be necessary to observe, that this extreme narrowness only exists at some few points and for short lengths: until, however, the obstructions are removed, it is sufficient to prevent any other means of traffic through the streets, than that carried on by porters, or pack-beasts of burden. If we now admit the roads and streets are so narrow, and ill paved besides, that traffic by any description of wheel-carriage is impracticable, we cannot fail to perceive how costly it must be to carry on a sufficient communication between a centre of commerce so situated and a railway-station distant a mile off or more: such a circumstance alone will prove that the adoption of such a position for an establishment of this nature, is an ill-considered and unwise proceeding. Merchants and tradesmen cannot remove their stores, warehouses, offices, and shops to the vicinity of the station, and many years must elapse before it can be hoped, if it ever may be expected, that such buildings will be erected round a station, even if it be otherwise located under the most promising conditions. Men of business are the most gregarious in their habits, and even if a few were to attempt to do this, they would immediately find themselves isolated from business.

The consequence of such a state of things is, that the ready communication which should exist between the rails and the centre of commerce—one of the most important requisites of railway establishments under any circumstances, but more particularly under those such as above mentioned—is utterly lost and defeated. This facility of communication is the more necessary, that a large proportion of the produce brought down from inland, or to be carried up into the interior, almost always requires to go through various processes of preparation and packing before it is sent away for sale.

When the station and the centre of trade are situated so far apart under such circumstances, the loading and unloading, the damage incurred, the carriage, besides the trouble involved, are much more costly than would be anticipated amongst all our carrying facilities; one way or other the consequences fall on the railway Company, whose prospects of traffic must be obstructed by such interferences; but what must be more important still, as regards the interests of the country, and therefore those of the railway, is that the future development of agriculture, manufactures, and commerce is greatly impeded: those ulterior advantages form the important objects to be sought after on Eastern railways, for great immediate traffic is not to be expected from lands which we know to be only partially cultivated and most deficient in means of communication; but the natural productiveness of the land is so very great, and it is otherwise so favourably situated, that once railways and branch roads are established, it will yield far greater supplies to the rest of the world, and those of a most valuable kind, than is generally anticipated. At present, with the deficient means of transport at command over the country, its natural wealth and possible accessibility from inland to its ports are almost a dead letter: beyond a limited radius the carriage of the most valuable goods will not pay, and in the understanding of this condition, the East ably rivals the most civilized nations of Europe.

With the knowledge that has been acquired by railway experience, any attempt to establish an important railway station at a distance from the centre of all business and commerce would never be thought of in railway countries; and it is at least surprising that it should ever have been contemplated in Turkey, and still more that it should have been carried into effect. It is to be hoped that the expectations deceived, which have been the consequence, will produce the only good result that may be looked for, and that is a sufficient warning to prevent such an attempt being repeated.

When goods, either the produce of the lands or of manufactures, are brought in by railway to a station near an important city circumstanced in the conditions above mentioned, the carriage to and from the station by porters, or by camels when these are to be obtained, is as expensive as the railway carriage over a distance of thirty or forty miles, and may be more so at certain seasons of the year, when the caravans are all engaged, and it may be difficult to obtain sufficient means of transport for carrying any large quantity of goods.

If the town and station, such as we now refer to, be situated on the coast, some amount of sea-works will in all probability be required, in immediate communication with the line of railway, and with such arrangements that the least possible amount of loading and unloading and of carrying backwards and forwards be necessary for all goods: with no other means than porters and pack-animals to carry such goods, even over a distance of only a mile, between the station and the centre of trade, the work must involve a very considerable expense, risk of damage, loss of time, and unnecessary trouble, all of which are greatly annoying to merchants, and obstructive to the development of goods traffic, such indeed being the very evils which railway appliances are intended to remove. Instead, however, of producing any such result, a station established near a large town, under the conditions above mentioned, only tends to increase and perpetuate every one of the obstructions from which engineers and all the talent connected with railways have so earnestly and successfully endeavoured to disencumber commerce. If, in addition, the sea-works are constructed in shallow water, these ill conditions are greatly magnified, for the jetty is unapproachable by the vessels of larger burden, on board of which merchants so very much prefer to ship their goods: harbour works under these circumstances are a source of the most useless expenditure of money. Of course, in Europe, with the knowledge acquired for many years past, such occurrences would be neither tolerated, nor thought of.

In almost all cases it would be something worse than needless, on account of the large expense that would be incurred, to think of constructing all the buildings of a terminal station in the heart of a town; and only the possibility of being misinterpreted, renders it necessary to mention that all the principal constructions should be built at some distance outside of the city; indeed, in almost all cases, all that would be necessary under the conditions here referred to, would be to bring the goods down into the centre of trade, and in most cases a tramway through some of the streets would be the only requirement to effect this. To accomplish even this, no doubt that here and there it would be required to pull down a few houses through some of the ill-built streets, but immediately outside the centre of the active business population, this would not prove a very serious affair, more particularly if the earliest opportunity be taken to close the purchase with the owners. It is only after the works have been for some time in progress, and large sums of money have been expended on them, that the demands of purchase-money will be raised beyond the actual value. However this may be, the writer's experience has amply convinced him that in the East, and in all countries similarly situated as regards roads in large towns, and the existing means of traffic upon them, it is absolutely indispensable that the company who wish to secure a remunerative traffic should carry goods into the very centre of trade.

When a site has been determined on, either for a terminal or intermediate station, some considerable amount of uncertainty very often existing as to the future development of the traffic, it will in many cases be found a prudent course, not to hasten the construction of all the permanent buildings, but to be content for a few years with useful temporary constructions; such always as may be sufficient and serve requirements for carrying on the traffic, and yet economical, both as regards materials and workmanship.

In a year or two after the opening of the line, we shall be able to judge by experience, and there is no other mode under conditions so new, of ascertaining to a certainty, how and in what ways the traffic will become developed; where buildings for various purposes may best be constructed, and where goods stations and warehouses, &c., may best be established; what should be their capacities and with what appliances they should be furnished for permanent use, as also where passenger traffic will require the most accommodation.

We are all aware, at the present age of engineering knowledge, how he most careful investigations into these subjects, and how the most studied calculations based upon them, have been repeatedly baffled by circumstances as they have arisen afterwards; this having been the case even after some years' experience in the great railway countries, where it may fairly be supposed that we had most of the reasonable means of forming a correct judgment, how very much more likely is it that calculations will be defeated in totally different countries and climates, where not only railways, but even all other means of carrying on any considerable traffic, more particularly with rapidity, have yet to be established.

The erection of temporary buildings, intended only to be used for a few years, would give time to acquire all the information required, experimentally: they would be of economical construction, which would give the means of directing capital into channels much more remunerative than masses of masonry constructed on mistaken sites; we should certainly be less liable, after experience acquired as to matters of which previously there was no knowledge whatever, to construct a large building where one much smaller would be sufficient; we should be able to form more judicious arrangements generally in relation to subjects of which we should have acquired some actual experimental information; we should have facilities for collecting leisurely and economically the most important materials afterwards to be required; and even if the buildings temporarily erected had all to be taken down some few years after, the materials could be mostly all worked up into the new constructions, or serve in their erection. Where once, however, large and expensive buildings have been provided in a situation ill-judged, no amount of talent, judgment, or experience brought to bear afterwards, however diligently, can remedy evils which have been made permanent.

All these considerations, based upon experience of these matters in the East, have convinced the writer that it will be wise in many cases to be satisfied at first, and to a considerable extent, with temporary timber buildings; such as have been, and are still numerously built for many most important European lines of railway; surely that which is sufficient for the enormous traffic these railways obtain, should be ample, at least for a time and in many instances, where the carrying trade has all to be developed, and where, moreover, the largest proportion of the traffic must, as the general rule, for years to come consist of goods.

As to the sufficient durability of the material in the climate, there need be no apprehension: when the writer left Asia Minor, there was a large temporary engine-shed, which had been constructed full three years before, for the repairs of locomotives, and which then continued in most satisfactory condition in all respects. Much must of course depend on the quality of the timber and upon the treatment it receives; if of reasonably good quality and fairly seasoned, it will be found that—*except* in foundations, where it should all be creosoted—it works very satisfactorily, the steadiness of the climate being more in its favour than might at first be supposed.

The great error too often committed with regard to the employment of timber, is to leave the logs generally saturated with water, exposed for weeks to the excessive heat of the sun; it consequently dries unequally, and of course splits in every direction. When first sawn up, the slabs, planks, &c., are full of imperceptible shakes, which the heat, however, soon renders evident enough; under these conditions it is admitted willingly that the climate does indeed mischief more than sufficient, and the consequences of building with timber under such circumstances are easy enough to realize; for wherever and in whatever shape it may be thus ill-used, it is of course split and rent in every direction.

Instead of allowing the timber to soak for six months or a year in a sea-pond, so as to be certain to come out most curiously honeycombed, to the depth of two or three inches, from the attacks of the worm, which in hot climates is of a very large size, it should at once be landed, and stacked under just such sufficient shelter as to screen it from the rays of the sun during the great heat of the day. The writer would hardly venture to mention such a recommendation but that he has seen some thousands of pounds' worth of timber rendered utterly valueless from want of such simple and ordinary precautions.

Temporary buildings, constructed of timber under proper treatment, would not only give satisfactory results as regards the circumstances above-mentioned; but in every respect they would be found superior to large stone buildings constructed of such indifferent masonry as to be inferior even to the ordinary stone-built erections of an Eastern town, and as to elicit from a first-class man, the opinion that the whole must come down from the first shake of an earthquake, even though such a building were *decorated* (?) with numerous plaster mouldings and cornices, and the whole of its walls covered with a veil of the same material, but so badly laid on as to fall off in numerous patches and thus form a new pattern of mural decoration.

In almost all cases it will be a needful precaution to secure ample room round the site for approaches; the ordinary road traffic by long lines of camels and numerous horses, renders a large area of station-yard more necessary than in Europe, the caravans being by no means convenient to dispose of.

Long platforms are desirable near towns and villages of any importance, and wherever there is a Greek or Roman Catholic, or Armenian population, provision must be made for an occasionally very large influx of pleasure-passengers on holy days. This is a description of passenger traffic which very much may be done to increase; only a small proportion of the platform needs generally to be covered, and unless for very important stations, planking is unnecessary. A station, whether terminal or intermediate, where accommodation is required for this kind of intermittent traffic, should not only occupy a considerable area, but should have abundance of siding at both ends of the platform, so as to hold several trains to be dispatched in succession. For intermediate passenger-stations, situated a few miles from large towns, there will generally only be required the most simple building accommodation.

In some districts provision will have to be made for cattle, which may become a subject of considerable traffic, if special attention be given to it. To accomplish this, cattle-pens must be provided, with sidings apart from the ordinary traffic of the stations, and to which there must be ordinary access, without in any way interfering with the other business of the line. Facilities and encouragement should be afforded for the establishment of slaughter-houses at the station most convenient to the town for this purpose. In the East, and most probably in many other countries similarly situated, the slaughter of cattle is carried on in a very primitive and disgusting manner, and almost in the streets. If proper arrangements could be made, and it is not a very difficult matter to accomplish, this might be remedied with great public advantage, and the assistance of Government might readily be secured. This would in many cases bring considerable traffic in cattle on to the line.

Where there is so much travelling on horseback as there is in the East, the subject of docks for loading and unloading horses is one requiring attention: they should be placed so as to be out of the way of the ordinary passenger traffic. They are generally best placed at the extremity of a terminus; but must be of easy access from the approaches: spare lines and turn-tables are the best accommodation stations can be provided with to facilitate this traffic.

Generally, it may be observed that we shall most certainly not find a traffic prepared and ready to come on to the line, and that almost always we may expect that we shall have to put ourselves out of the ordinary routine, in order, as it were, to create it and bring it on to the rails.

Platforms should not be less than two feet above the rails, and always of ample width. For large stations, much attention should be given to ventilation, which should be abundant, and Louvre ventilators should be made to open and shut at pleasure. This is another matter to be attended to with care in hot climates, where the winters are sometimes very severe, though of short duration. Ample drainage must be provided. A ticket platform is desirable in the East; but the separation of the classes is unnecessary, and more likely to give offence than to do any good.

The comforts of the several classes of *employés* on the line deserve considerable attention, for in such climates a long day about a station is a hard trial, the more so that at first the Company's means necessitates economy as to the number of men employed.

Glass in roofs requires to be introduced with great care and moderation in all hot climates, on account of the power and high vertical angle of the mid-day sun; and in the design of permanent constructions, the subject of earthquakes must not be lost sight of: in the building of every good house in the East, and indeed in all countries subject to these subterraneous shocks, abundance of bond timbers, well tied together, in the shape of plates, braces and struts, is largely introduced: the best guide in these matters is to study the habits of the people themselves.

CHAPTER XI.

ROADS, TRAMWAYS, ETC.

About a century and a half since, many portions of the most highly civilized countries in Europe were traversed by roads on which most, if not all, of the traffic was carried by pack-horses; gradually this state of things was amended, until at last the country became covered as it is now by a network of well-constructed roads, canals, tramways, and railroads. If at the time referred to a first-class trunk railway had been made through one of these districts on which the pack-horse did all the traffic, it is probable that it would not have been a very remunerative undertaking; from want of means of communication and of all the advantages that spring therefrom, not more than a third, and, perhaps, not one-sixth of the land was under the cultivation as existing at the present time; there was besides almost a total absence of the many industrial establishments which have been erected all over the country since those days. But if instead of a trunk line of railway only, branch tramways and roads in communication with the main line, each adapted to the work to be done, had been laid down to the different centres of population, it is not unlikely that in these districts, agriculture and trade would have become rapidly developed, and so in all things that constitute the wealth of a country; if in addition to this there had been some neighbouring nations in highly improved conditions as to arts and sciences, various improvements would have been speedily imported and a still greater change effected; but certainly the mere construction of a railroad *by itself* would never produce such a revolution.

The introduction of tramways and roads in Europe, in the mineral and industrial districts, was the first step in the development of their wealth: the establishment of these in America in a very short period of time, in conjunction with economically constructed railways, produced an abundant source from which the resources of the land expanded with unparalleled rapidity and magnitude.

In a vast empire, situated from various circumstances in a most primitive state as regards internal communications, however great in the other respects, similar means should be adopted. However abundant the natural resources and productiveness of the land, it is the only system which, according to all experience, will produce beneficial results under such conditions.

In very many respects the East, and probably most of those foreign countries with fine climates, into which it is now sought to introduce railways, are in a state exactly similar to that above supposed, with however this exceptional advantage, that they have been favoured with a climate productive to affluence of every description of the most valuable vegetation, and often with great mineral wealth, which Europe is not only anxious to import, but often suffers from not being able to obtain.

This very simple relation of existing conditions makes it sufficiently evident that for a railway to be a successful undertaking, either for a company or a nation, in these distant climates, roads are as indispensable as the construction of the railway itself: as an instance, we may take either a wheat or cotton-growing district, or lands capable of producing these commodities: when in close proximity to the railway, the goods can afford to pay for carriage by beasts of burden, but there is a limit to this, and it does not extend far; and when the range of distance is beyond the radius of this limit, cultivation will not pay, and the lands remain barren, and must remain so until some road suitable to the country is made through the district. Nor is the simple expense of traffic by pack-carriage only to be taken into consideration: combined with this, we must take into calculation the damage arising from pack-carriage in many instances—the loss of time if there is to be any traffic to pay for railway expenditure, and even limits to the obtaining the number of pack-animals that would be required to carry all the produce of a country cultivated to any considerable extent. All this is very easily conceivable if we merely inquire mentally where would be the railway traffic, the agricultural produce, or the state of cultivation of France or England if everything had to be carried by pack-horses. If we could only bring our minds to conceive the possibility of such a state of things, it is not improbable that an engineer's first thought would be to lay down an organized system of tramways where now we have turnpike and public roads.

Although the country in the East is not yet in a condition to warrant the establishment of such tramways to every small town at some distance from a railway, it is necessary always to keep in mind the important fact that a horse can draw on such ways from about thirty to forty-five times as much as he can carry, accordingly as the way is laid with stone or iron, and according to the condition in which the road is kept.

If any such road be made from a railway to a town, say twenty miles off, the first advantage will be to obtain the carriage of every pound of produce the inhabitants can immediately raise, and obtaining it at once in large quantities, instead of in such handfuls as it may pay them to send by pack-carriage. In the next place, the inhabitants being perfectly alive to the forwarding of their own interests, would immediately bring as large an area of land under cultivation as they possibly could, as soon as tangible means existed for realizing a profit upon the produce, such as a railway would then afford them. Immigration to the favoured locality would at once ensue, and the very labourers on the works would be the first to settle there. There would be a motive for cultivation where none whatever now exists.

In most parts of the East, and in hot climates generally, the weather is dry for eight or nine months in the year, and except with earth of a very sandy or friable nature, earthen roads, tolerably well made, when the inclination of the ground is not very steep, will answer a great number of useful purposes; the dry atmosphere and great heat tend to harden the ground throughout the summer so as to render it fit to receive the traffic of carts adapted to the roads. Where the country is only slightly undulating, or where nearly level, as it is often found in the East, except in the immediate proximity of mountains of volcanic origin, which rise very abruptly from the face of the earth—it will be found very easy to lay out roads with a maximum inclination of one in a hundred, without having to recur to earthwork in their formation, except so far as the ground is side-lying, and in many cases a ditch cut on each side will give sufficient material for making the road: here and there, but it would certainly not be found the general rule, it might be necessary and advantageous to lower some of the elevations and wheel the stuff into the depressions, in following any line of track already adopted in the country: but this would only be very slight, the easiest line of country being always selected by the camel-drivers on account of the nature of a camel's build, which makes steep ascents and descents particularly burdensome.

When, to avoid length of road, a diversion is made from an already beaten track, care must be taken to avoid a line which would involve severe gradients, as a short length of any such road would limit the load to be drawn along the whole length, or involve the necessity of additional power of draft for ascending steep portions of road. One in thirty is, however, admissible for short distances; but where they are of any considerable length, or much steeper than this, recourse could be had advantageously to short lengths of fairly paved roads, or of stone or plank trackway: if this is impracticable, some sacrifice must be made to avoid a long steep gradient, as it would, as before observed, completely overrule the amount of load that might be otherwise brought along a great length of level road.

These circumstances are exactly amongst those which should be studied at an early stage of railway establishment, because whilst the works are being carried on, both plant and labour are on the ground, which, in such countries and climates as we are now dealing with, are at least one half the battle in the matter of light earthworks, as already observed on the subject of reservoirs for irrigation. As far as practicable, roads, or portions of them, should always be completely finished before the wet season sets in, when the rains will tend to consolidate them, whilst unfinished parts will suffer considerable damage. The heavy floods to which these countries are liable, also render it very advisable to adopt lines of road with slight ascents and descents in preference to those perfectly level, as they afford much better drainage.

From fifteen to sixteen feet wide is almost always ample, as this affords sufficient width for two lines of carts passing each other; and those portions which are paved, or laid with stone, plank, or tramway, may be single, and the remainder will serve as a turn-out for descending carriages, which should give way to those which are ascending.

In high thermometric regions generally, the winter season of the year is that in which a great deal of agricultural labour is performed, and one therefore when beasts of burden are all engaged in field-work; this tends, of course, at such time of the year, to diminish considerably the number of animals that can be employed in carrying to and from the railway. But many portions of this season are adapted to the work of road traffic, and much of the agricultural produce is not before ready to be carried away, which render it the more necessary that all possible measures should be adopted to facilitate common means of transit.

Amongst the useful memoranda relating to road-making, the following may be mentioned :—

One in 125 is a good inclination for surface drainage of a road.

The force of traction on the following description of roads may be taken . . . . at

1.	Railway in perfect order	$\frac{1}{280}$
2.	The best stone trackways	$\frac{1}{170}$
3.	New road covered with gravel 5 in. thick	$\frac{1}{18}$
4.	Solid earthen causeway gravelled $1\frac{1}{2}$ in.	$\frac{1}{16}$
5.	Gravel road laid on earth	
6.	Road of sand or gravel	
7.	Broken stone road—deep ruts and mud	$\frac{1}{19}$
8.	Ditto ditto —ordinary condition	$\frac{1}{25}$
9.	Ditto ditto —ruts and mud	$\frac{1}{33}$
10.	Ditto ditto —in fair order	$\frac{1}{36}$
11.	Causeway of earth—very good order	$\frac{1}{41}$
12.	Broken stone road on paved foundation	$\frac{1}{51}$
13.	Ditto ditto in perfect order	$\frac{1}{67}$
14.	Ditto ditto ditto	$\frac{1}{73}$
15.	Well-made pavement	$\frac{1}{54}$ to $\frac{1}{71}$
16.	Plank road	$\frac{1}{100}$

Resistance of Gravity on the following Inclinations.

On a level, or	0 in 100,	a horse can draw	1·00
On a rise of	1 in 100	,,	·90
,,	1 in 50	,,	·81
,,	1 in 44	,,	·75
,,	1 in 40	,,	·72
,,	1 in 30	,,	·64
,,	1 in 26	,,	·54
,,	1 in 24	,,	·50
,,	1 in 20	,,	·40
,,	1 in 10	,,	·25

Force required (according to Sir H. Parnell) to draw a Stage-coach at different Speeds and Inclinations.

	Force of Draught required in lbs.		
Inclination.	6 miles per hour.	8 miles per hour.	10 miles per hour.
1 in 20	268	296	318
1 in 26	213	219	225
1 in 30	165	196	200
1 in 40	160	166	172
1 in 600 (or level)	111	120	128

Deductions from Morin's Experiments on Traction.

The resistance, or "traction," is directly proportional to the *load,* and inversely proportional to the diameter of the wheel.

Upon a paved or a hard macadamized road the resistance is independent of the width of the *tyre* when it exceeds from 3 to 4 inches. On compressible roads the resistance diminishes when the breadth of the tyre increases.

At a walking pace the traction is the same, under the same circumstances, for carriages with *springs* or without them.

Upon hard macadamized and upon paved roads, the traction increases with the velocity; the increments of traction being directly proportional to the increments of the velocity, above a speed of about

$2\frac{1}{4}$ miles per hour; but it is less as the road is more smooth, and the carriage less rigid or better hung.

Upon soft roads of earth, or sand, or turf, or roads freshly and thickly gravelled, the traction is independent of the velocity.

Upon a well-made and compact *pavement* of hewn stones, the traction at a walking pace is not more than three-fourths of that upon the best macadamized road under similar circumstances: at a trotting pace it is equal to it.

The *destruction of the road* is in all cases greater as the diameters of the wheels are less; and it is greater in carriages without than with springs.

If the friction upon a plank road is such as to require upon a level a force of draught equal to $\frac{1}{100}$ of the load, the total force required for an ascent of $\frac{1}{30}$ will be $\frac{1}{100}+\frac{1}{30}=\frac{1}{100}=$ about $\frac{1}{17}$, or the resistance of gravity would be $\frac{5}{6}$ of the whole resistance; whereas, on an earthen road, where the resistance due to friction on a level is $\frac{1}{20}$, the total force required for an ascent of $\frac{1}{20}$ will be $\frac{1}{20}$ for friction $+\frac{1}{20}$ for gravity, total $\frac{2}{20}=\frac{1}{10}$, of which only one-half would be due to gravity. On a rough road, where the friction is great, any inclination forms a much smaller part of the resistance than does the same inclination on a smooth road, on which it is much more severely felt.

"*Profit of avoiding a Hill.*—If the improvement be avoiding a hill, the resistance of gravity is to be compared with that of friction. Suppose that a certain road ascends a hill which is a mile long, and has an inclination of 1 in 10, and descends the other side, which has the same slope, and that a level route can be obtained by making the road a mile longer: it is demanded how much may be expended for this purpose. Suppose that the friction on this road is 1-40th, and that 50,000 tons, as before, pass over it annually. On the original road of 2 miles the force of draught required to overcome *friction* is $\frac{50000\times2000}{40\times100},=25000$ horse-power at 3 miles per hour, or $\frac{25000\times2}{3}=16667$ horses for the 2 miles, $=1667$ days' work of a horse. To overcome the *gravity* of the loads on the inclination of 1 in 10 requires $\frac{50000\times2000}{10}=10{,}000{,}000$ lb.

or 1 mile = 333,333 lb. for 30 miles = 3333 days' work of a horse. The descent of a mile on the other side of the hill is not a compensation, for a horse will have no more to take down the descent than he had dragged up the ascent. The total annual labour to overcome both friction and gravity on these 2 miles is therefore 1667 + 333 = 5000 days' work of a horse.

"Upon the new road proposed there is no inclination to overcome, but an extra mile of length. The force of draught upon it due to friction is $\frac{50000 \times 2000}{40}$, = 2,500,000 lb. for 3 miles, = 250,000 lb. for 30 miles, = 2500 days' work of a horse. The saving of labour is therefore 5000 − 2500 = 2500 days' work of a horse, = 750*l.*, interest of 12,500*l.*, which amount (deducting cost of repairs of the extra mile) may be expended in making the new road.

"These calculations have been made for extreme cases, in order to make the principle more striking; but the advantages deduced from them have fallen short of the truth, since only the original amount of traffic has been considered, while all experience shows that it is very greatly increased by any improvement in the means of transport, particularly by the increased speed, which is an incidental advantage which we have not taken into account."

The fact of the money-cost of animal labour in India being one-sixth as great as it is in England and America, will of course greatly diminish the amount that it would be worth while to spend in saving animal labour on any Indian line of communication.

"We have now to consider what is the greatest and what is the least inclination allowable on a road. The loss of power on steep inclinations is much greater than that merely due to gravity, for besides the increase of draught carried by that force, the power of the horse to overcome it is much diminished upon an ascent, and even in a greater ratio than that of a man, owing to its anatomical formation and great weight. Though a horse on a level is as strong as five men, yet on a steep hill it is less strong than three, for (according to Emerson) three men carrying 100 lb. each will ascend faster than a horse carrying 300 lb."

CHAPTER XII.

WROUGHT-IRON BRIDGES—PLATE, LATTICE, AND TRELLIS GIRDERS.

THE subject of wrought-iron girder bridges is one acquiring greater importance every year, more especially as regards railway construction at present; judging by what has been done in twenty years, we should not like to attempt looking into the future of those constructions.

In the foregoing pages, we have pointed out many instances where bridge masonry in the East must be expensive, difficult, and troublesome, in consequence of many circumstances we have attempted to describe. We believe that, notwithstanding the increased cost, on account of transport of material, considerable economy would often be effected by a greater introduction of light wrought-iron bridges.

In these pages on the subject, we shall consider more particularly of iron bridges for distant climates, and make all our observations as practical as may be, and only for the subject before us.

In the following example of a few practical calculations for the dimensions of wrought-iron plate girders,

Let L be the length or span;

D, the total depth of girder;

d, the depth of girder from centre to centre of flanges;

a, the sectional area of top or bottom flange;

w, the weight per foot run of bridge and of live load that may come upon it;

W, the total weight.

S, the strain.

s, the strain to which each square inch of metal in top or bottom flange is to be subjected.

Put all the weights in tons.

The lengths, depths, and breadths, we may take in feet or in inches, but whichever we adopt, had better be retained throughout the calculations.

The first calculations are usually made to obtain an approximation for the sectional areas of top and bottom flange.

In any loaded girder supported at each end, half the weight will rest on one support, and the other half will be borne at the other end.

The weight of the girder, loaded or unloaded, will be the agent to bend or break the beam, and this agency, multiplied by the half-length of beam will be the strain S, or moment of stress at the centre.

But the resistance to this stress is in the strength of the beam, and this strength must be made up of the depth, breadth, and power of cohesion or resistance in the fibres of the material; and if we call this resistance f, we shall have perfect equilibrium when,

$$f=S.$$

We will now suppose a case for a girder of 100 feet span: we will assume D, the total depth of girder, as $\frac{1}{12}$th of the span, which is generally received as the most economical depth for a straight girder; then D will be equal to 8′ 4″, or 8·333.

Take w, the weight per foot run of span, for dead weight of bridge and live load to come upon it, at 1·75 tons per lineal foot.

If for a plate-girder bridge of this span, we have two girders for a single line, then the weight per foot run upon each girder will be $\frac{1{\cdot}75}{2}=0{\cdot}875$ tons per foot run on each beam.

The effect of a distributed load over a beam is at the centre the same as though half that distributed were placed there.

Then,

$$\frac{0{\cdot}875}{2}\times 100=43{\cdot}75 \text{ tons}=W, \text{ the weight at centre.}$$

The formula for finding the sectional area is,

$$a=\frac{W\,L}{4\,s\,d}$$

then,

$$\text{area}=\frac{43{\cdot}75\times 100}{4\times 5\times 8{\cdot}333}=26{\cdot}25, \text{ sectional area of flanges at centre of girder.}$$

But taking the load as distributed over the girder, the formula is

$$a=\frac{\mathrm{W\,L}}{8\,s\,d}$$

Here W, is equal to $0{\cdot}875\times100=87{\cdot}5$ tons;

then, $$\frac{87{\cdot}5\times100}{8\times5\times8{\cdot}33}=26{\cdot}25,$$ sectional area as before.

It is safe to check one calculation by the other, always remembering that the differences in the figures merely arise from either considering the load as distributed over the length of the girder, or half that load placed at the centre.

The bottom flange in our girder is under tensile strain, and the top flange is under a compressive strain. In wrought iron the ratio of resistance to tension and compression is taken as 20 to 16; then we should have, $16:20::26{\cdot}25:32{\cdot}81$ for sectional area of top flange, that is, ¼ more than in the bottom flange.

It must be here observed, that in a riveted plate girder, the holes punched for the rivets in the bottom flange are in fact so many defects, from the plates being under tension, and because the operation of punching injures the material between the rivet holes. This is not the case in the top flange; and for this reason, the sectional area of the top plates is very often made the same as that of the bottom flange. Much depends on the quality of the material, of the workmanship, and on the practical skill with which the details of angle-irons, strips, packing covers, covering angle-irons, T irons, stiffening ribs, &c., are designed; when the sectional area of the top is made otherwise equal to that of the bottom flange, it is often increased by the addition of strong angle-irons, riveted underneath along the outside edges.

In the above we have given D as the total depth of the girder, and *d* as the depth from centre to centre of the flanges; it is this latter which is now to be used in the calculations.

It has already been observed that to establish equilibrium between the strain on the girder and its power of resistance,

f must be equal to S.

The following formula gives us the means of ascertaining this:

$$\frac{\mathrm{W\,L}}{4}=\frac{s\,a\,d}{2},$$

where W, as before, is the load at the centre, and equal to half the distributed load.*

Now this is,

$$\frac{43{\cdot}75\times100}{4}=\frac{\text{strain pr. sq. in.}\times\text{areas}\times\text{depth}}{2}$$

Let us now examine how this comes out in figures.

$\frac{43{\cdot}75\times100}{4}=1093{\cdot}75$, for the first member of the equation.

$$\begin{array}{lr}
\text{sectional area of top flange} & =26{\cdot}25\\
\text{,,} \quad \text{,,} \quad \text{bottom ,,} & =26{\cdot}25\\
 & \overline{52{\cdot}50}\\
\left.\begin{array}{l} s\text{, assumed strain per square}\\ \quad\text{inch of metal . . .}\end{array}\right\} & \begin{array}{r} 5\\ \hline 262{\cdot}50\end{array}\\
\left.\begin{array}{l} d\text{, depth of girder from centre}\\ \quad\text{to centre of flanges. .}\end{array}\right\} & \begin{array}{r} 8{\cdot}333...3\\ \hline 2187{\cdot}5\div2=1093{\cdot}75=\frac{s\,a\,d}{2}\end{array}
\end{array}$$

But this is assuming that the top flange is to be equal in area to the bottom flange, and that it is to be strained by a compressive force of 5 tons to the square inch.

If we make the area of the top flange ¼ greater than that of the bottom flange, we have, as before, 32·81 square inches for the sectional area, and assuming that it is to be strained by 4 tons to the square inch, we shall have,

$$\begin{array}{ll}
\text{for top flange,} & \frac{s\,a\,d}{2}=\frac{32{\cdot}81\times4\times8{\cdot}33...3}{2}=546{\cdot}875\\
\text{and for bottom flange,} & \frac{s\,a\,d}{2}=\frac{26{\cdot}25\times5\times8{\cdot}33...3}{2}=\underline{546{\cdot}875}\\
 & \qquad\qquad\qquad\qquad\qquad 1093{\cdot}750 \text{ as before.}
\end{array}$$

It will now be seen how f depends upon the strain per square inch of metal.

When all the above dimensions are given, and we have to find the load which the girder is capable of bearing, we have the following formula :—

$$W=\frac{4\times s\times a\times d}{L},$$

---

* We venture to repeat this, because errors are often made from taking half the distributed load collected at the centre, for the whole of the load over the girder.

where W, half the distributed load, is assumed as placed at the centre of the girder.

And, $$W = \frac{8 \times s \times a \times d}{L},$$

where W is the load, supposed uniformly distributed along the girder.

As yet we have only found the approximate sectional areas at the centre for the top and bottom flanges. We have now to find these are as from the centre towards the supports, along the top and bottom flanges, compressive in the upper, and tensile in the lower flange.

These areas may be found from the rectangles of the segments into which the span is divided, and this supplies a simple rule for calculating the required sectional areas at different points along the girder, when we have found the strain in the centre, by a simple rule of proportion.

In the case of the girder we have in hand, let it be required to find the sectional area of either flange at 10 feet from the centre; this will divide the girder into two segments of 40 feet for one, and 60 feet for the other, which call A C and B C;

Then as

half the span ^{2}: sectional area at centre :: A C × B C: area required,

or,

50^2: 26·25 :: 40 × 60 : 25, sectional area at 10 feet from centre of girder.

And at 20 feet from the centre, it is

50^2 : 26·25 :: 30 × 70 : 22, sectional area at 20 feet from centre of girder.

If we adopt 4 tons strain per square inch, the following is a very simple formula for ascertaining the areas at once :—

$$\frac{w \times x}{8\,d}\,l - x;$$

where w, is the weight per foot run;
„ x, the shorter distance from the abutment;
„ l, the span, and therefore $l - x$, the longer distance from the abutment;
„ d, the depth.

In the case of the girder for which we are now calculating, we shall have the following for sectional area at *centre* :—

$$w=0{\cdot}875,$$
$$x=50,$$
$$8\,d=8{\cdot}33...33\times8=66{\cdot}666,$$
$$l-x=50.$$

Then, $\frac{0{\cdot}875\times50}{66{\cdot}66...6}\times50=32{\cdot}5$ square inches at centre.

And at 20 feet from the centre,

$$w=0{\cdot}875,$$
$$x=30,$$
$$8\,d=8{\cdot}33...33\times8,$$
$$l-x=100-30=70.$$

Then,

$\frac{0{\cdot}875\times30}{66{\cdot}66...6}\times70=27{\cdot}5$ square inches at 30 ft. from abutment at each end.

Before the details of a girder can be got out, it is necessary to calculate the areas along the whole length of the girder, and the very simple formula given above gives us the means of plotting the curve, so that we may refer to it when determining the lengths of the plates or otherwise providing for their disposition; if a horizontal straight line be drawn, equal in length to the span of the opening, and divided at given distances, verticals may be set off at these points, on which we may lay down, in length, the amount of the different sectional areas required at different distances from the centre, and this will be found a simple way to avoid much unnecessary calculation, at least in the first dispositions to be made.

In the above calculations, made for the use of the purely practical man, who objects to *x*'s and *y*'s, we have made use of easy numbers for our calculations, such as 100 feet span and 5 tons strain per square inch of sectional area; but it is very doubtful whether our iron manufacturers have yet succeeded in making iron to be trusted with such strain even under any circumstances; all the experiments made for some years past make this very doubtful.

It must also be remembered that the sectional area obtained first only approximately, is the gross and not the net section of metal, and without any allowance for deductions. Also it is calculated for a passive load; it is statical and not dynamical.

Amongst the most valuable experiments made as yet upon this subject, are those recorded by Mr. Edwin Clark and Dr. Fairbairn.

The following table and observations of Mr. Clark's will always be of high value as regards the strength of boiler plate:—

No.	Description of Plate.	Breaking Weight per square inch.	Ultimate Extension in parts of the Length.
1	Plate $\frac{11}{16}$th inch thick, neck $1\frac{1}{2}$ inch long. Selected as bad iron, fracture bright and crystalline, brittle, broke readily with a blow from a hammer	22	—
2	From the same plate	21	$\frac{1}{40}$
3	Plate $\frac{1}{2}$ inch, neck 6 inches. Selected as bad iron, containing two laminæ of crystalline metal, one-third of the whole section	18	$\frac{1}{180}$
4	Plate $\frac{1}{2}$ inch, neck 5 inches. Selected as a good plate, about $\frac{1}{10}$th of the section crystalline . . .	19	$\frac{1}{48}$
5	Plate $\frac{1}{2}$ inch, neck 4 inches. Iron perfectly uniform and fibrous, supported the weight fifteen minutes .	21	$\frac{1}{8}$
6	Plate $\frac{11}{16}$th inch thick, neck 5 inches. Iron good, $\frac{1}{40}$th of the section crystalline	19	$\frac{1}{36}$
7	Plate $\frac{1}{2}$ inch, neck 5 inches. Iron fibrous except $\frac{1}{50}$th of the section .	18	$\frac{1}{23}$
8	Plate $\frac{1}{2}$ inch, neck 50 inches . .	19·6	$\frac{1}{57}$
9	Plate $\frac{5}{8}$ inch, neck 50 inches . .	19·3	$\frac{1}{33}$
10	Plate $\frac{1}{2}$ inch, neck 7 inches . .	19·6	$\frac{1}{19}$
11	Plate $\frac{1}{2}$ inch, neck 7 inches . .	20·2	$\frac{1}{24}$
12	Plate $\frac{1}{2}$ inch, neck 50 inches . .	18·7	$\frac{1}{59}$

"From the mean of the above experiments the ultimate tensile strength of boiler plate appears to be 19·6 tons; and it is worthy of remark that the ultimate strength is remarkably constant, although the iron comes from different makers from Staffordshire, Derbyshire, and Shropshire. The ultimate extension, on the contrary, is extremely irregular; indeed, some of the brittle, crystalline irons, selected as bad, which fractured suddenly without much increase of length, actually supported more weight than the more fibrous and ductile iron.

"In all these cases the iron was drawn in the direction of the fibre. In order to test whether the strength is influenced from this cause, two plates were selected, and from each plate two specimens were cut out, of similar form to those used in the experiments above. One specimen in each pair was cut out in the direction of the fibre, and the other across the fibre; in other respects they were precisely similar in form and dimensions. The following were the results :—

		Tons.		Tons.
“ Ultimate strength when drawn in the direction of the fibre . . .	Exper. 1,	19·66	Exper. 2,	20·2
Ultimate strength when broken across the fibre	Exper. 1,	16·93	Exper. 2,	16·7

“The ultimate extension was also twice as great when the plate was broken in the direction of the fibre.

“The ultimate strength of wrought iron, derived from experiments on 1-inch bars, has been usually taken at 25 tons per square inch. This conclusion is evidently erroneous as regards boiler plate; indeed, this strength was not obtained from any iron used at the works.

“The best scrap rivet iron, made by Messrs. Mare at their London works, the quality of the iron being unusually good, and the fracture beautifully fibrous, broke on an average with 24 tons per square inch, or 18·84 tons per circular inch. The length of the round rods experimented upon was 60 inches, the diameter ⅞ths of an inch, and the mean ultimate extension (which was uniform) was ⅛th of the length. The rods diminished very visibly in diameter before they were fractured, and drew into a conical neck at the point of failure.”

It would be very desirable to have the original and fractured sectional areas of these plates, but from this table, the mean tensile breaking weight of boiler plate is 19·86 tons.

As regards wrought iron girders, or at least plate girders, the experiments made on so grand a scale in the Britannia Bridge model, will always be of the greatest value, for although a plate girder differs from a cellular girder with double web, there will always be a great analogy as regards the strain on the top and bottom plates.

In that tube the length between the supports was 75 feet, and the depth from the bottom to the centre of the top cells was 51 inches, or 4′ 3″, the extreme depth being 54 inches, or 4′ 6″, this being rather more than *one-sixteenth* of the span.

The sectional area of top was 26·5 square inches.
„ „ bottom „ 22·45 „

The weight of tube between supports was 6·25 tons.

The breaking weight in centre was 89·1 tons.

As the depth of the beam is to half the span : : half the weight to the tension exerted at the centre of the bottom and compression at top; this proportion in the tube gives us 392·6. This, divided by sectional area of the top, gives 14·8 tons of *compression* per square inch, which crushed the material and destroyed the tube.

And $\frac{392{\cdot}6}{22{\cdot}45}=17{\cdot}5$ tons was the tensile strain at bottom, which, however, did not fail under the strain, but would have supported $\frac{1}{17}$ more.

Experiments, as valuable as they are interesting, have been made by Mr. David Kirkaldy, of Glasgow,* and from these we submit the following, the iron being obtained promiscuously in the market:—

IRON PLATES.

Farnley—Sample Iron; ¾ Inch plates.

Original Area. Sq. in.	Fractured Area. Sq. in.	
		25·3 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·750	0·605	27·9 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·750	0·669	23·6 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		26·08 tons, mean of 4, breaking weight per square inch of original area for tensile strains, applied lengthways.
		24·5 tons, mean of 4, breaking weight per square inch of original area for tensile strains, applied crossways.

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* Results of an Experimental Inquiry into the Comparative Tensile Strength and other Properties of various kinds of Wrought Iron and Steel, by David Kirkaldy.

SAME WORKS.

Promiscuous Iron ; $\frac{1}{4}$ Inch plates, or considerably above $\frac{7}{32}$.

Original Area. Sq. in.	Fractured Area. Sq. in.	
		25·2 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·750	0·649	27·3 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·750	0·669	22·1 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		26·1 tons, mean of 3, breaking weight per square inch of original area for tensile strains, applied lengthways.
		24·1 tons, mean of 6, breaking weight per square inch of original area for tensile strains, applied crossways.

BRADLEY AND CO.

L F *promiscuous iron ; plates from $\frac{11}{32}$ to very nearly $\frac{1}{2}$ inch.*

		24·1 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·623	0·524	27·2 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·776	0·702	21·1 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		25·4 tons, mean of 6, breaking weight per square inch of original area for tensile strains, applied lengthways.
		22·8 tons, mean of 6, breaking weight per square inch of original area for tensile strains, applied crossways.

LOW MOOR.

Promiscuous; $\frac{5}{16}$ plates.

Original Area. Sq. in.	Fractured Area. Sq. in.	
		22·9 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·624	0·477	25·8 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·624	0·548	21·1 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		23·4 tons, mean of 5 breaking weight per square inch of original area for tensile strains, applied lengthways.
		22·5 tons, mean of 5 breaking weight per square inch of original area for tensile strains, applied crossways.

GLASGOW.

Promiscuous; Best Boiler, from $\frac{8}{16}$ to $\frac{21}{32}$ plates.

		22·9 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·700	0·623	25·1 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·930	0·854	20·4 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		24·0 tons, mean of 6 breaking weight per square inch of original area for tensile strains, applied lengthways.
		21·8 tons, mean of 6 breaking weight per square inch of original area for tensile strains, applied crossways.

SAME WORKS.

Promiscuous; Best Best, from about $\frac{1}{4}$ up to nearly $\frac{13}{16}$ plates.

Original Area. Sq. in.	Fractured Area. Sq. in.	
		20·2 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·775	0·693	25·8 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·988	0·959	16·6 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		23·8 tons, mean of 18 breaking weight per square inch of original area for tensile strains, applied lengthways.
		18·6 tons, mean of 14 breaking weight per square inch of original area for tensile strains, applied crossways.

GOVAN.

Promiscuous; about $\frac{13}{32}$ plates.

		23·2 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·826	0·648	25·7 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·816	0·784	20·6 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		24·4 tons, mean of 6 breaking weight per square inch of original area for tensile strains, applied lengthways.
		22·0 tons, mean of 6 breaking weight per square inch of original area for tensile strains, applied crossways.

CONSETT.

Best Best promiscuous, from about $\frac{7}{16}$ to $\frac{10}{32}$ plates.

Original Area. Sq. in.	Fractured Area. Sq. in.	
		22·1 tons, mean breaking weight per square inch of original area for tensile strains, applied lengthways and crossways.
0·651	0·554	25·8 tons, highest breaking weight per square inch of original area for tensile strains, applied lengthways.
0·706	0·671	18·2 tons, lowest breaking weight per square inch of original area for tensile strains, applied crossways.
		23·9 tons, mean of 10 breaking weight per square inch of original area for tensile strains, applied lengthways.
		20·4 tons, mean of 10 breaking weight per square inch of original area for tensile strains, applied crossways.

ANGLE IRON.

Tensile Breaking Weights per square inch of original area.

	Size.	Highest. Tons.	Lowest. Tons.	Mean. Tons.	Contraction of Fractured Area. Mean per cent.
Farnley	$\frac{9}{16}$	28·4	26·2	27·3	20·9
Glasgow Best Best Scrap	$\frac{5}{8}$	26·	23·9	25·	15·0
Eagle Best Best . . .	$\frac{5}{8}$	25·2	23·8	24·4	13·7
Glasgow Best Best . .	$\frac{9}{16}$	25·5	24·5	25·	15·4
Albion Best	$\frac{5}{8}$	25·8	24·1	25·	14·0

Two of the lowest breaking weights do not exceed 20·7 and 19·2 tons per square inch.

IRON BARS.

Tensile Breaking Weights per square inch of original area of Section.

	Contraction of Area at Fracture, Inch.	Highest. Tons.	Lowest. Tons.	Contraction of Area at Fracture. Inch.	Mean. Tons.	Description of Bar.
Lowmoor .	0·5639	27·8	26·4	0·5216	27·0	Rolled bars, 1 inch square.
	0·1735	30·3	28·9	0·2015	29·6	Forged from 1¼ inch round bars.
Bowling . . .	0·2828	29·3	26·2	0·4433	27·9	Rolled bars, 1 inch round.
Farnley . . .	0·4006	28·6	26·6	0·4006	27·2	Do. do.
Bradley & Co., S. C. . .	0·2372	28·4	27·2	0·2902	27·7	Do. ⅞ inch round.
Govan B. Best.	0·1830	29·7	27·5	0·0918	28·9	Do. ¾ inch round.

Another bar of Bowling (numbered 127) 1 inch diameter, turned from 1¼ inch round bar, broke with 27·1 tons per square inch of original area; the original area being 0·″7854, and the fractured area 0·″3848.

The following remarks refer to the effects produced, as regards the breaking weight and contraction of area, by subjecting iron to various kinds of treatment:—"Bowling, 1045—1050, Table N, were forged down off the same bar as that numbered 127, Table B; 1045, highly heated, and suddenly cooled in water, bore 76,839" (34·3 tons per square inch of original area) "and only contracted 34·5 per cent., instead of 51, with 60,817 lbs. as previously, when merely turned down, proving that the iron was made much harder by the treatment. 1047, similarly treated, but not so hard, contracted 44·7, with 71,538" (31·9 tons) "cooled in oil, contracted 25·7, with 65,934" (29·4 tons) "1049, 41·6 with 63,341 (28·2 tons); 1050, cooled in tar, 40·5 with 62,864. . . . The hardening effect produced by cooling in water is likewise shown in bolts cut out of armour plate."

The following concluding observations, in relation to these numerous experiments, are deserving of every consideration in the design of work:—

"The breaking strain does *not* indicate the quality, as hitherto assumed.

"A *high* breaking strain may be due to the iron being of superior quality, dense, fine, and moderately soft, or simply to its being very hard and unyielding.

"A *low* breaking strain may be due to looseness and coarseness in the texture, or to extreme softness, although very close and fine in quality.

"The contraction of area at fracture, previously overlooked, forms an essential element in estimating the quality of specimens.

"The respective merits of various specimens can be correctly ascertained by comparing the breaking strain *jointly* with the contraction of area.

"Inferior qualities show a much greater variation in the breaking strain than superior.

"The breaking strain and contraction of area of iron plates are greater in the direction in which they are rolled than in a transverse direction.

"Iron, when fractured suddenly, presents invariably a crystalline appearance; when fractured slowly, its appearance is invariably fibrous.

"The appearance may be changed from fibrous to crystalline by merely altering the shape of specimen so as to render it more liable to snap.

"Iron is less liable to snap the more it is worked and rolled.

"The mixed character of the scrap-iron used in large forgings is proved by the singularly varied appearance of the fractures of specimens cut out of crank-shafts.

"The specimens were generally found to stretch equally throughout their length until close upon rupture, when they more or less suddenly drew out, usually at one part only, sometimes at two, and, in a few exceptional cases, at three different places.

"The shearing strain of steel rivets is found to be about a fourth less than the tensile strain.

"Screwed bolts are not necessarily injured although strained nearly to their breaking point.

"A great variation exists in the strength of iron bars which have been cut and welded; whilst some bear almost as much as the uncut bar, the strength of others is reduced fully a third.

"Iron is injured by being brought to a white or welding heat, if not at the same time hammered or rolled.

"The breaking strain is considerably less when the strain is applied suddenly instead of gradually, though some have imagined that the reverse is the case.

"The contraction of area is also less when the strain is suddenly applied.

"The amount of heat developed is considerable when the specimen is suddenly stretched, as shown in the formation of vapour from the melting of the layer of ice on one of the specimens, and also by the surface of others assuming tints of various shades of blue and orange, not only in steel, but also, although in a less marked degree, in iron.

"The specific gravity is found generally to indicate pretty correctly the quality of specimens.

"The density in some descriptions of iron is also decreased by additional hot-rolling in the ordinary way; in others the density is very slightly increased.

"The density of iron is decreased by being drawn out under a tensile strain, instead of increased, as believed by some."

The following observations were made by the *Engineer* for July, 1862, on the Strength of Boiler Plates and the Hydraulic Test for Boilers.

"In the course of a recent legal inquiry at Guildhall, a few engineers, practised in locomotive mending, expressed strong opinions against testing boilers by hydrostatic pressure. A boiler had exploded on the London and North-Western Railway, and Mr. ———, late locomotive superintendent of that line, and who, if anybody was officially responsible for the disaster, was allowed to appear as a witness, and give evidence that it was imprudent to test the strength of boilers. Mr. ———, too, had not a single fact to adduce in proof of the impropriety he sought to establish. He never tested his boilers—had never even seen a boiler tested—but left them to blow up whenever their untested barrels became sufficiently weakened by corrosion. Mr. ———, too, a gentleman who has for many years had the mending of the ——— engines, thought it injudicious to subject boilers to the hydraulic pump, although he could not say exactly why, except that that was his opinion. Mr. ———, of the ———, and some one else, whose name we forget, was of much the same mind. These witnesses, or some of them, affected the greatest ignorance of the fact that the hydraulic test was regularly employed on other lines, where, possibly in consequence of the test, boilers do not explode, and whereby the shareholders are not subjected to costly suits growing out of explosions. Thus, on the Eastern Counties, the South Eastern, the Lancashire and Yorkshire, the Newcastle and Carlisle, the North British, the Caledonian, the Edinburgh and Glasgow, and other lines, both new and old boilers are regularly tested up to twice their working pressure. In France, all wrought-iron steam. boilers of whatever description must, by law, be tested by the hydraulic pump up to three times their working pressure, cast-iron boilers being tested up to five times their working pressure. In America all Government boilers must bear a hydraulic pressure two-thirds greater than that at which they are intended to work, and a similar test is now enforced by the police of New York upon upwards of 3000 steam boilers at work in that city. Mr. Fletcher, the engineer to the Manchester Association for the Prevention of Steam Boiler Explosions, and who has occasion to examine more boilers, perhaps, than any other man living, applies and strongly recommends the hydraulic test, and so does Mr. Longridge, the engineer to the Steam Boiler Assurance Company. Many of the agricultural engine-makers test their boilers also in the same manner.

"Now, does this test injure a boiler, and if not, is it a useful test? Let us see. According to the best authorities, the elasticity of iron, and therefore iron itself, is permanently injured by a strain somewhere between one-third and one-half its breaking strength. If a locomotive boiler, the bursting strength of which is, as it should be, 800 lbs. per square inch, be tested with the force pump to 400 lbs., the chances are that the iron will be injured. If it be tested to 250 lbs. abundant experiment goes to show that no harm will be done, and the boiler will remain safe, to all intents and purposes, under a steam pressure of 125 lbs. per square inch. But we cannot know, until we have actually burst open a boiler, what its ultimate strength really is. The boiler to which, upon a general faith in the maker's stamp on the plates, and in the style of riveting, we may assign a probable strength equal to 800 lbs. on the square inch, may contain a hidden flaw, or—as did the new ——— iron boiler which burst four years ago in Messrs. ———'s workshops—a rotten plate with a strength of but 4⅔ tons per square inch, and the bursting strength may be but 150 lbs. or 200 lbs. In this case a hydrostatic pressure of 250 lbs. would search out and proclaim the defect at once. But if the flaw were such that the bursting pressure was, say, 400 lbs., then it is probable that a test of 250 lbs. would, while failing to disclose weakness, actually injure the boiler, and possibly lead to explosion. The boiler, the bursting of which led to the suit already mentioned, had an ultimate strength of somewhere about 425 lbs. only per square inch. That is to say, it was 49¾ inches in internal diameter, and it was made of ⅜-inch plates single riveted. The original strength of the plates may be taken as 51,000 lbs. per square inch, so that, for each inch in length of the boiler, the full strength of the ¾ square inch of sectional area of iron plate, weakened to the extent of 44 per cent. at the single riveted joints, would be 21,420 lbs., and as the pressure would be exerted diametrically across the boiler upon a line of 49¾ inches, the quotient would be 430½ lbs. per square inch, which would be the extreme bursting strength of the barrel. That such a boiler would have been fatally injured (although, perhaps, not actually broken open) under the French hydraulic test of three times the working pressure, or 360 lbs., there can be no doubt whatever. A test of 250 lbs. would, probably, have been dangerous, not, of course, while making the test, which, even if it tear open the boiler, can do so only quietly, but dangerous on account of the injury which it would probably do to the iron, thereby predisposing to explosion afterwards. Yet we shall show that this does not support Messrs. ———'s, ———'s, and ———'s opinions as to the impropriety of the hydraulic test, for iron is only injured by injuring its elasticity, and its elasticity is injured only when it shows, after being strained, permanent elongation of the fibres. Thus a boiler, the bursting strength of which was 430½ lbs., would unquestionably be found to have had its diameter slightly but permanently increased under a strain of 360 lbs., and, in all probability, under a strain of 250 lbs. So far as we are aware, the practice of measuring the diameter of boilers, under successive increments of strain, has never been initiated. Yet why should it not be begun? Take the exact diameter of the largest ring of a boiler when the interior is charged with cold water to a pressure of 100 lbs., measure it again with the pressure increased successively to 150 lbs., 200 lbs., 250 lbs., and so on possibly to 300 lbs. Then ease off the pressure, and note how much, if at all, the iron has been permanently stretched. If at 100 lbs. pressure, or when entirely free from strain, the diameter is exactly what it was before the test, the boiler is safe with any ordinary load on the safety-valves. If permanently enlarged to any considerable extent, the boiler needs immediate strengthening. To say that boilers, upon the soundness of which so much depends, should not be tested at all, does little credit either to the skill or astuteness of men like Messrs. ———. Iron, in any shape upon which we may have occasion to depend, should always be tested. No engineer would think of permitting an iron bridge to be opened until it had been loaded with the greatest weight which could ever come upon it in the way of traffic. The engineer, however, does not rest satisfied with the mere discovery that his bridge is not broken down under the test, but he carefully notes the deflection of his arches or girders, and observes whether they take a permanent set, and if so, how much. The safety of the bridge is inferred, not so much from the fact that it has survived the ordeal of a load of locomotives, or of pig-iron, or ballast, but from the amount and character of its deflection. Every chain cable received into the royal navy is tested, and the action and effects of the test strain are exactly analogous to those of the hydraulic test for boilers. And just as in the case of a cable which suffers no permanent elongation under strain, we may conclude that a boiler which is not permanently distended by the hydraulic test is in no respect injured by it. This point being settled, it requires but little consideration to perceive that the test by the force-pump must be a useful one. Indeed, to our mind, it is indispensable to anything like security. It may be safely, cheaply, and expeditiously applied—the oftener the better—and as long as the boiler, upon careful measurement before and after the test, shows no permanent distension, there is no fear of its bursting from weakness, original or produced. But without a pair of callipers large enough to take in the boiler, and without careful observation during and after the application of hydrostatic pressure, we should fear it might injure the boiler. The disclosures in the case of the exploded boiler of the London and North-Western engine have convinced us that there are many so-called 'first-class' engines which could not safely be submitted to any test much beyond their ordinary working pressure, and we must suppose that Messrs. ———, who can hardly be ignorant of this fact, make it the sole ground of their objection to the hydraulic test."

Dr. Fairbairn has made the following observations on the Effects of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Bridges and Girders:—

"It is upwards of fifteen years since a series of experiments were made to determine the value of wrought-iron riveted plates in the form of rectangular tubes, when employed as girders spanning rivers and ravines, for the support of roads and railways. Those experiments led to the erection of the Conway and Britannia Bridges on the Chester and Holyhead Railway, and determined the form in which such structures should be designed, as also the strength necessary to resist the strain of the passing loads. A new theory of construction was thus developed, and a new era established in the history of bridges. Since that time some thousands of bridges, composed entirely of wrought-iron plates, have been erected, supporting roads and railways with a degree of safety not attainable with any other description of material.

"The construction of the Britannia and Conway bridges of the tubular form led to the introduction of tubular girder, plate, and various forms of lattice bridges, all founded on the same principle.

"The tubular bridges were originally designed so that their ultimate strength should be six times the greatest rolling load which could be placed upon them after deducting the weight of the tube. This was considered a fair margin of strength, but subsequent considerations have induced in many cases an increase of this margin of resistance to five or six times the maximum rolling load and permanent load taken together.

"Owing to the great success in the first examples of wrought-iron bridges, a great demand for them arose in every direction, and numbers were made without any regard to principle, or the laws of proportion so clearly and satisfactorily developed in the Millwall experiments. The result of this was the erection of many weak bridges, so disproportioned as to be at the point of breaking with little more than double their own weight. This, together with the bad system of contractors tendering by weight, and the employment in some cases of *bad iron and bad workmanship*, have brought discredit upon the margin of strength at first considered sufficient. No construction requires greater care, or a more minute attention to sound principles of construction, than wrought-iron girders. The lives of the public depend on the knowledge and skill of the engineer, and the fidelity of himself and the contractors in the selection of the material.

"The defective and abortive structures which followed the first successful application of wrought iron led to doubts and fears on the part of some engineers, who contended for a margin of eight or even ten times the heaviest load, whilst others considered a much smaller surplus of strength sufficient. In the evidence given before the Commission on Railway Structures in 1848-9, this variety of opinion was fully shown. Mr. Brunel allowed the maximum load to be one-third to two-fifths of the breaking weight. Mr. Grissel and Mr. May considered one-third sufficient; Mr. Rastrick, Mr. Barlow, and others adopted one-sixth; Mr. Hawkshaw, one-seventh; and Mr. Glynn, one-tenth. Ultimately the authorities at Whitehall appear to have decided, but upon what data is uncertain, that the maximum tensile strain on any part of a wrought-iron structure, arising from the permanent load and the greatest rolling load together, should not exceed five tons per square inch. This corresponds with a strength of at least four times the rolling load and the permanent load taken together.

"This requirement of five tons per square inch on the part of the Board of Trade appears to be founded on no fixed principle, and is far from satisfactory. It is well known that the powers of resistance to strain of wrought iron depend very much upon the form in which it is combined, and unless the proportions of the parts are permanently established, the five ton tensile strain may lead to error."

"Twenty tons per square inch is believed to be about the average breaking weight of the ordinary qualities of wrought-iron; and by common consent among the majority of engineers, five tons per square inch is considered as the maximum strain to which the material of any structure like a wrought-iron bridge should be subjected. Unless there has been a very general misunderstanding upon this matter, the maximum strain of five tons per square inch should include both the strain produced by the weight of the structure itself, and that produced by the greatest moving load. When an authority like Dr. Fairbairn, for example, tells us that the strength of a given bridge is six times the maximum load, his statement is generally taken to mean that the maximum strain upon the material of the bridge is but one-sixth of its ultimate strength. This appears to be a very liberal margin of strength, and quite enough to satisfy the most exacting *Inspecteur* of the *Ponts et Chaussées*. If, however, from the total breaking weight of the bridge, the weight of the structure itself be deducted, and the strength then inferred by comparing the remainder of the ultimate strength with the moving load only, the apparent margin of safety, although it may appear very wide, may be, nevertheless, very narrow. Dr. Fairbairn has calculated that, at a span of between 1800 feet and 2000 feet, an iron tubular bridge would be barely capable of sustaining its own weight, and hence it could carry no weight whatever. If the weight of a bridge be equal to one-third of its breaking load, an additional moving load equal to one-half the weight of the structure would increase the strain upon the material to one-half of the total strength, although the strength of the bridge, beyond supporting its own weight, would be four times the moving load."

In apportioning the sectional area of the flanges and the proportions of a girder, we have to keep in view, as regards experiments made, the effects of weight applied gradually, and of weights applied suddenly in the centre, and that of a rolling load, for a railway train does not find its way suddenly to the centre of a bridge; the weight is brought to bear first at one end of the bridge, and from this point rapidly on to the centre; the load is active instead of passive, but is different to a load suddenly applied at the centre, and induces a preparation in the materials in the girders of a bridge to arrive at the condition of *ut tensio sic vis.*

With regard to the plates, the angle-irons, packing strips, &c., it is to be considered more particularly as regards the bottom flange, that we can only calculate on the strength of the aggregate, in so far as the whole are wrought by good workmanship into a closely connected and continuous part of the beam; long lengths of angle-irons, and of packing strips, where the latter are used, with the joints made sound by angle-iron covers, may with safety have their sectional areas included in the aggregates of section of flange.

The following observations and practical advice, extracted from a paper read by Dr. Fairbairn before Section G of the British Association, September, 1861, are so valuable as to the design and construction of wrought-iron girders, that we here venture to reproduce them :—

"I have been led to inquire into this subject with the utmost care, not only on account of the imperfect state of our knowledge in this respect, but from the want of definite instructions from the authorities whose business it is to secure the safety of the public and enhance the value of these constructions. To accomplish this, I have, in the following experimental researches, endeavoured to arrive at the limit to which a girder may be strained without injury to its powers of resistance.

"During the years 1858-9, I was engaged in the construction of a viaduct of 230ft. span, for the purpose of carrying the Inverness and Aberdeen Junction Railway over the River Spey. Concerning this viaduct, an important discussion arose between one of the Government Inspectors of Railways, Captain Tyler, R.E., and myself, having reference to the margin of strength necessary to prevent disruption from the strain and vibration of the passing load. It has been thought by some that long-continued impacts ultimately destroy the cohesive properties of beams. In cases of extreme loads this has been proved to be the case, both in the following experiments and in the earlier ones of the Royal Commission; but it is very imperfectly known what fraction of the breaking weight operating in a long series of changes as a traverse strain would, in a given time, absolutely lead to fracture.

"As the designs, calculations, and proportions of the superstructure of the Spey Bridge were entirely in my hands, I found myself responsible for the security of the structure. My original estimate of the strength of the bridge was :—

Sectional area of top	120 square inches
„ bottom	110 „
Depth of girders	16 feet
Span of girders	230 „

"Hence, for the centre breaking weight of one girder, we have, from the formula deduced from the experiments at Millwall:—

$$W = \frac{a\,d\,c}{l} = \frac{110 \times 16 \times 80}{230} = 612 \text{ tons,}$$

and for the breaking weight of the bridge, with the load distributed, $612 \times 4 = 2448$ tons.

"To this calculation the Board of Trade objected, on the following grounds:—

"That I did not deduct the area of the rivet-holes in the bottom web.

"That I included two packing strips, of a total area of 12½ ins., which, not having their joints covered, did no duty in strengthening the bridge.

"That the depth ought to be calculated between the centres of gravity of the top and bottom flanges, thus reducing *d* from 16ft. to 15ft. 3ins.

"Lastly, that the constant 80 is too high for tubular girder bridges, 74·4 more nearly representing the result of the experiments.

"Captain Tyler's data are therefore:—

Area of bottom	99 inches
Depth	15 feet 3 inches
Span	230 feet

"Centre breaking weight of one girder =

$$W = \frac{99 \times 15{\cdot}25 \times 74{\cdot}4}{230} = 488{\cdot}37.$$

"Breaking weight of bridge, load distributed, $= 488{\cdot}37 \times 4 = 1953{\cdot}5$ tons, or about one-fourth less than my own calculations.

"With the exception of the objection as to the packing strips, however, I cannot consider Captain Tyler's views correct. I do not deduct the rivet-holes, because the formula is obtained from the gross area of the model tube, nor can I accept 74·4 as the proper constant for girders with cellular tops. But in calculating the strength of a bridge in which a proper ratio is preserved between the top and bottom areas, the constant derived from a similar case is, in my opinion, the most appropriate one to employ. It is manifestly unfair to use a constant derived from a beam of defective proportions, and composed, as is not unfrequently the case, of inferior iron. Again, however theoretically advantageous it may be to calculate the depth between the centres of gravity of the top and bottom flanges, it has been found sufficiently accurate hitherto to take the whole depth, if this has also been done in deducing the constant.

"Making allowance for the absence of the covers over the joints of the packing strips, the strength of the Spey Bridge was not less than 2200 tons with the load distributed, and provided a further allowance were made for the thickness of the sides, it would bring the strength up to the original computation of 2448 tons.

"But, in the consideration of the margin of strength, a more important difference arises between myself and Captain Tyler. The permanent weight of the bridge between the abutments is 375 tons, and the weight of the platform 46 tons, so that the total permanent load is 421 tons. The maximum rolling load for a double line of rails was ultimately taken by Captain Tyler at 408 tons, the weight employed by him in testing the bridge.

"Captain Tyler considers that the ultimate strength of the bridge ought to be four or five times the total maximum rolling load added to the total permanent load: that is, that the strength of the Spey Bridge should amount to 4100 tons instead of 2448, which I had provided for in my calculations.

"On the other hand, I have been accustomed to regard the permanent weight of the bridge and the rolling load as acting independently. From the breaking weight I deduct the permanent load, and consider the remaining resistance as the surplus strength for resisting the rolling load.

"To both of these methods of calculating the margin of strength certain objections attach. With very small bridges they agree nearly with one another. With larger bridges the method I follow gives weaker bridges than those desired by the Government Inspector. The larger the bridge becomes, the more rare are the occasions on which the rolling load is at its maximum. With very large bridges, equal in span to those over the Conway and Menai Straits, both lines can scarcely ever be loaded up to the limit of two tons per foot run. Now the fault of the allowance of strength demanded by the Board of Trade appears to me to be that it takes no account of this fact. It provides bridges which become increasingly strong in proportion to their work as the span is increased. Hence, in fact, the Conway Bridge, strong and durable as it has proved itself, does not reach the margin of strength which the Board of Trade require. In fact, in order to raise it to that standard, it must be increased to at least five times its present strength, since, with bridges of such spans, every addition to the strength adds also in a high degree to the permanent weight of the bridge. It remains, therefore, to be considered how far the weight of bridges of large span acts by its inertia in antagonism to the rolling load.

"On the other hand, the rule I have employed does appear to provide bridges which, in very large spans, are weaker in proportion to their work than in small spans. Within the limits ordinarily required,—that is, not exceeding three-hundred feet span,—I have not found bridges so proportioned, to offer any signs of weakness. The strength of the Conway and Britannia bridges, although considerably in excess of six times the rolling load, is nevertheless much nearer to that than the proportion of five tons per square inch of section.

"In Plate 203 I have drawn curves showing the relation of strength, weight, and span, which are given by the rules I have discussed, between the limits of 50 and 400 feet span. The dotted lines represent the ratio of the centre breaking weight of the bridge to its span, and the ratio of the permanent weight of the bridge to the span, whatever that may be. The black lines represent the same ratios according to my own rules.

"These curves show: First, that for spans of less than 100 feet the Board of Trade rule gives weaker bridges than my own. Second, that in very large spans the Board of Trade rule gives bridges enormously stronger than my own. Third, that at or below three hundred feet of span the limit is reached at which it is practically possible to erect tubular girder bridges of the same proportions as those across the Conway and Menai Straits, in which the maximum strain does not exceed the Board of Trade standard. The reason of this is the high ratio in which the weight of the bridge increases in large spans. In fact, the weight increases as the cube where the strength increases as the square of the lineal dimensions.

"The above considerations have led me to experiment upon the influence of vibration in causing the rupture of beams and bridges. For this purpose I have constructed a small wrought-iron plate beam of twenty feet clear span and sixteen inches deep, representing the proportions of one of the girders of the Spey Bridge, and exposed it to conditions similar to those of a bridge subject to changes of load and vibration, as produced by the passage of trains, and in proportion to the heaviest rolling load.

"The proportions of this beam are as follows:—

Top—Plate, $4 \times \frac{1}{2}$ .... = 2·00 sq. inches area.
Angle-irons, $2 \times 2 \times \frac{5}{16}$ .... = 2·30 "
Total...... = 4·30 "
Bottom—Plate, $4 \times \frac{1}{4}$ .... = 1·00 "
Angle-irons, $2 \times 2 \times \frac{3}{16}$ .... = 1·40 "
Total...... = 2·40 "
Web—Plate, $15\frac{1}{4} \times \frac{1}{8}$ .... = 1·90 "
Total area of beam .... = 8·60 "
Weight of beam .... = 7 qrs. 3 lbs.
Probable breaking weight .... = 9·6 tons.

"This beam having been fixed securely, as will be seen by reference to the illustration (see THE ARTIZAN, August 1st, 1860, p. 219), the experiments were commenced. In the woodcut referred to, A is a shaft and pulley driven by a water-wheel; B a wheel and pinion, giving motion to the connecting-rod C, which lifts the end of the lever and load from off the beam shown in section at D, with the shackle and clip *a*. At the lower end of the connecting-rod C is a slot, made for the purpose of allowing the load to come fairly upon the beam before the next suspension. E the lever and F the scale for regulating the weights. On the top flange of the beam was stretched a gauge, to ascertain the deflections during the changes and vibrations produced by the different loads. By means of a water-wheel the continual lifting and releasing of the lever was continued night and day, and the number of changes of load was registered by a counter, D.

"The experiments were commenced by loading the beam to within a fourth of its breaking weight, and starting the apparatus. After more than half a million changes of load the beam appeared to have sustained no injury.

TABLE I.

Beam loaded to one-fourth of its Breaking Weight.

Total moving load.......................................= 5809 lbs.
Permanent load (or half weight of the beam)......= 434 lbs.
Margin of strength by Board of Trade ....= 3·4 to 1.
Strain on bottom flange ....= 4·35 tons per sq. inch.

Date.	Number of Changes of Load.	Deflection at centre of beam.	Date.	Number of Changes of Load.	Deflection at centre of beam.
1860.			1860.		
March 21	......	0·17	April 13	268,828	0·17
„ 22	10,540	0·18	„ 14	281,210	0·17
„ 23	15,610	0·16	„ 17	321,015	0·17
„ 24	27,840	...	„ 20	343,880	0·17
„ 26	46,100	0·16	„ 25	390,430	0·17
„ 27	57,790	0·17	„ 27	408,264	0·16
„ 28	72,440	0·17	„ 28	417,940	0·16
„ 29	85,960	0·17	May 1	449,280	0·16
„ 30	97,420	0·17	„ 3	468,600	0·16
„ 31	112,810	0·17	„ 5	489,769	0·16
April 2	144,350	0·16	„ 7	512,181	0·16
„ 4	165,710	0·18	„ 9	536,355	0·16
„ 7	202,890	0·17	„ 11	560,529	0·16
„ 10	235,811	0·17	„ 14	596,790	0·16

"The beam took at first a permanent set of about 0·01 inch, which did not appear to increase afterwards. The beam was then subjected to experiment with an increased load, equivalent to one-third the breaking weight.

TABLE II.

Load equivalent to one-third the Breaking Weight.

Total moving load.......................................= 7406 lbs.
Permanent load...= 434 lbs.
Margin of strength by Capt. Tyler's rule ......= 2·7 to 1.
„ „ by my own rule ....= 2·9 to 1.
Strain on bottom flange ....= 5·47 tons per sq. inch.

Date.	Number of Changes of Load.	Deflection in inches.	Date.	Number of Changes of Load.	Deflection in inches.
1860.			1860.		
May 14	......	0·22	June 7	217,300	0·21
„ 15	12,623	0·22	„ 9	236,460	0·21
„ 17	36,417	0·22	„ 12	264,220	0·21
„ 19	53,770	0·21	„ 16	292,600	0·22
„ 22	85,820	0·22	„ 21	327,000	0·23
„ 26	128,300	0·22	„ 23	350,000	0·25
„ 29	161,500	0·22	„ 25	375,650	0·23
„ 31	177,000	0·22	„ 26	403,210	0·23
June 4	194,500	0·21			

"The beam had now made a million strokes, partly with a load of one-fourth, and partly with a load of one-third the breaking weight. As it was uninjured, the load was increased to nearly one-half the breaking weight.

TABLE III.

Load equivalent to one-half the Breaking Weight.

Total moving load .... = 10,050 lbs.
Permanent load .... = 434 lbs.
Margin of strength by Capt. Tyler's rule ...... = 2·05 to 1.
„ „ by my own rule .... = 2·09 to 1.
Strain on bottom flange .... = 7·32 tons per sq. inch.

Date.	Number of changes of Load.	Deflection in inches.	Remarks.
1860.			
June 27	...	0·35	
„ 28	5175	...	The beam broke.

" With a load of one-half the breaking weight the beam gave way after 5175 changes of load. It appears, therefore, that it is not safe to build bridges in which the rolling load would bear this proportion to the breaking weight.

"The beam was then taken down and repaired; a patch was riveted across the fracture in the bottom plate, so that the area of sound plate remained as before. The experiments were then renewed; 158 changes of load were sustained with a load equal to one-half the breaking weight. The load was then reduced to two-fifths the breaking weight, and 25,900 changes of load were sustained. Lastly, the load was reduced to one-third of the breaking weight, and the results given in the following table were obtained.

TABLE IV.

Load equivalent to one-third of the Breaking Weight.

Total rolling load .... = 6359 lbs.
Permanent load .... = 434 lbs.
Margin of strength .... = 3·2 to 1.
Strain on bottom flange .... = 4·74 tons per sq. inch.

Date.	Number of Changes of Load.	Deflection in inches.	Date.	Number of Changes of Load.	Deflection in inches.
1860.			1860.		
August 13	25,900	0·18	Dec. 22	929,470	0·18
„ 16	46,326	0·18	„ 29	1,024,500	0·18
„ 20	71,000	0·18	January 9	1,121,100	0·18
„ 24	101,760	0·18	„ 19	1,278,000	0·18
„ 25	107,000	0·18	„ 26	1,342,800	0·18
„ 31	135,260	0·18	Feb. 2	1,426,000	0·18
Sept. 1	140,500	0·18	„ 11	1,485,000	0·18
„ 8	189,500	0·18	„ 16	1,543,000	0·18
„ 15	242,860	0·18	„ 23	1,602,000	0·18
„ 22	277,000	0·18	March 2	1,661,000	0·18
„ 30	320,000	0·18	„ 9	1,720,000	0·18
October 6	375,000	0·18	„ 16	1,779,000	0·17
„ 13	429,000	0·18	„ 23	1,829,000	0·17
„ 20	484,000	0·18	„ 30	1,885,000	0·17
„ 27	538,000	0·18	April 6	1,945,000	0·17
Nov. 3	577,800	0·18	„ 13	2,000,000	0·17
„ 10	617,800	0·18	„ 20	2,059,000	0·17
„ 17	657,500	0·18	„ 27	2,110,000	0·17
„ 23	712,300	0·18	May 4	2,165,000	0·17
Dec. 1	768,100	0·18	„ 11	2,250,000	0·17
„ 8	821,970	0·18	June —	2,727,754	0·17
„ 15	875,000	0·18			

"The following table gives a summary of the results obtained in this series of experiments.

TABLE V.

Summary of Results.

Experimental Table.	Load at Centre.		Ratio of Load to breaking Weight.	Tensile strain on Bottom.	Strain on Bottom after deducting Rivets.	Changes of Load.	Deflection.	Remarks.
	Changing.	Weight of Beam or permanent Load.						
	lbs.	lbs.		tons.	tons.		ins.	
I.	5809	434	3·4 : 1	4·35	5·91	596,790	0·17	Uninjured.
II.	7406	434	2·7 : 1	5·47	7·43	403,210	0·23	Uninjured.
III.	10050	434	2·05 : 1	7·32	9·92	5175	0·35	Broke.
IV.	6359	434	3·2 : 1	4·74	6·42	2,727,754	0·17	Uninjured.

"In using the numbers giving the strain in tons per square inch of the gross sectional area of the bottom, it must be remembered that a larger proportion is punched out for the rivet-holes in this small beam than in bridges. Taking the next column, which gives the strain on the metal of the bottom after deducting the rivet-holes, we find that the beam suffers no deterioration with strains of nearly 7½ tons per square in. With 10 tons per square inch the beam broke, after 5172 changes of load. Now as the limit of elasticity is reached at about 9 tons per square inch in ordinary boiler plates and bridge plates, it would appear that it is unsafe to load structures subject to a continually varying load beyond that point. Within these limits, however, we have no evidence that a deterioration of the structure takes place.

"The results given here apply chiefly to cases where nearly the whole load of the beam is a changing load, the weight of the beam itself being insignificant. It remains to be considered, in the case of large bridges, where the chief part of the load is permanent and stationary, and the lesser portion only changes, whether even greater strains than these would not be suffered with impunity. On this subject we have no experiments which apply to wrought iron, but in the case of cast iron some results have been obtained which have an important bearing on the question.

"In the first place, I have shown that where the whole load is permanent and stationary, cast-iron bars, loaded with three-fourths of the breaking weight, suffer very slight deterioration in the course of time; thus in the experiments recorded in the 'Report on the Effect of Time on Loaded Cast-Iron Bars,' published in the Transactions of this Association, it was shown that the increase of deflection of bars loaded with three-fourths of their breaking weight, amounted in the course of five years to 0·004 in. in the case of cold-blast iron, and to 0·009 in the hot-blast iron. That is, that there was a mean increase in five years of $\frac{1}{300}$ of the whole deflection of the bar. With a cold-blast bar loaded with above $\frac{9}{10}$ of the breaking weight, the increase in four years was $\frac{8}{1000}$ of an inch, or not more than $\frac{1}{180}$ of the whole deflection. These experiments would seem to show that, with a stationary load, materials may be loaded with impunity within the limit of elasticity, or nearly up to a force calculated to produce fracture.

"Secondly, in the case where part of the load changes and part is permanent, some experiments were made by the Commission on iron structures, which gave the following remarkable result: That additional loads spread uniformly over a beam, increased its power of resisting impacts. They found that beams of cast iron, loaded to a certain degree with weights spread over their whole length, and so attached as not to prevent the flexure of the bar, resisted greater impacts from the same body falling on them than when the beams were unloaded in the ratio of two to one. There is great difficulty in applying such results as these to the case of bridges of wrought iron, but at least they may serve to indicate the direction which should be taken in further experimental inquiries on this very interesting and important subject.

"On some future occasion I may have again to refer to this subject. For the present, I would advise that in all beams and girders, tubular or plain, the permanent load, or weight of the girder and its platform, should not in any case exceed one-fourth of the breaking weight; and that the remaining three-fourths should be reserved to resist the rolling load, in the proportion of six to one.

"As a general rule, these ratios of strength would apply to all bridges, but the strains would be least on the smallest bridges, which, in my opinion, is requisite on account of the frequency of neglect of smaller structures.

"I would earnestly direct the most careful attention to the laws which govern the resisting powers of girders exposed to transverse strains; to the best principle of uniting the joints, and, above all, to the selection of the best material, which, in the parts of girders subject to a tensile strain, ought always to sustain a test of from 22 to 24 tons per square inch. There is no economy in the use of inferior iron for this purpose, and its employment inevitably leads to a loss of character in the structure and danger to the public."

The duty of the web of a girder is to keep the flanges in true position and preserve the shape of the girder. The strain on the web is least at the centre and greatest at the bearings; it is very common in practice to make the quantity of metal in the web equal to half the quantity contained in both flanges; it is also often made by some engineers of equal thickness throughout, and by others nearly as thick again at the ends to what it is in the centre, which latter mode of distribution we prefer, since it is at the bearings that the greatest strain comes on this portion of the girder. A more important consideration, however, as regards the web, than the mere thickness of the plates, at least within practical limits, is the means employed to stiffen it and to prevent its buckling; this is effected by some engineers by the introduction of stiffening ribs connected with the plate by angle-irons, and by others by means of angle-irons acting as covers at all the vertical joints in the plates of the web, and cranked over on to the top and bottom flanges as far as the edges of the plates. At the ends of the girders, and also just where they bear on the edge of the abutments, stout stiffening ribs, connected with the web by angle-irons, should be introduced.

In a wrought-iron girder, the sectional areas from the centre to the bearings are diminished, theoretically, according to the strains, by decreasing the number of plates as we recede from the centre. In the case before us, for some fifteen feet on both sides of the centre of the span the plates would be of the same thickness throughout, after which they would gradually diminish in number, and consequently in sectional area, because in wrought-iron girders the widths remain the same throughout the length, from obvious reasons.

When the calculations have proceeded so far, the weight of the girder is calculated, as also weight of platform, ballast, sleepers, and rails, and the total weight of dead load is obtained more accurately than by the first approximation. The calculations are then gone into over again with better data; the lengths of the plates ascertained, the details of angle-irons, &c., are determined, and the net sectional areas may be definitively settled upon.

Braced-Girders.—Under this denomination may be included the almost infinite varieties of Triangular, Lattice, and Trellis girders. To judge by the numbers of large plate-girders now being constructed near London, this description of beam is in considerable favour for reasons of economy, even for girders of considerable span, and as this has been so decided by men of the highest practical eminence, we may rest satisfied that under *similar circumstances*, at least at present, the election has been judicious. Under the conditions, however, to which these pages mostly refer, it will be found that the most economical girders are pretty generally those of which the parts are comparatively of light burden, which may be easily carried, and put together in the most simple manner, always remembering all that has already been said upon the subject, and for this reason we consider the Warren or triangular girder preferable in most cases for the circumstances and conditions here referred to. *Practically* the webs will be found to weigh much the same; better bearings will be more easily obtained in the Warren girders; they may be designed so as to be more portable in parts. There is more riveting in the plate-girder, which is one of the descriptions of labour most desirable to avoid in the East.

In any braced or plate-girder, as mentioned above, the strains along the girder may be found by the rules already given, and the strains on the diagonals of an open girder may be found theoretically by the following formula:—

$$W \times n \times \frac{\lambda}{d},$$

in which W is the weight distributed according to n, the number of struts or ties, λ the length of a diagonal bar, and d, as before, the depth of the girder.*

When there is more than one, two, or three series of triangles, the quantity last obtained is to be divided accordingly.

There is also a practice of drawing a vertical line through the depth of the girder, and distributing the strain according to the number of diagonal bars intersected.

How very small the strain on the web is at the centre of a girder has been shown by Dr. Fairbairn in some experiments made by him on braced-girders, and recorded in his work, "On the Application of Cast and Wrought Iron to Building Purposes." It must, however, be remembered, that throughout its length the duty of the web is to keep the flanges in their true position.

Where the ties and struts are of wrought iron, the strain per square inch of sectional area may be taken at 4 tons for the struts, and at 5 tons for the ties.

The following memoranda may be found useful in making the calculations:—Sectional areas in wrought iron × 10 = lbs. weight per yard run; and sectional areas in square *inches*, multiplied by *length in feet*, and divided by 672 = tons weight.

In a continuous girder of two equal spans equally loaded, we shall have the conditions for each span of a single girder fixed at one end, and supported only at the other, with two points of contrary flexure at a certain distance from the central pier, and virtually the beam will have to be treated as one of three spans; in the two end bays the flanges will be in the conditions of girders, fixed at one end and supported at the other, with a strain tensile on the lower plates, and

---

* The above formula is the equivalent of the three following:—

$$\tfrac{1}{4}\,W \times \text{Nat. Cosecant} \times \text{Radius};$$

$$\tfrac{1}{4}\,\frac{W}{\text{Nat. Sine}} \times \text{Radius};$$

the angle being that which the diagonal bar makes with the horizontal, and the radius equal to half the base of the triangle;

$$\tfrac{1}{4}\,W \times \text{Nat. Secant} \times \text{Radius};$$

the radius being as before, but angle for this last formula being that which the diagonal bar makes with the vertical.

compressive on the top, and the reverse over the central part, which will be, when most highly loaded, in the condition of a girder loaded at both ends, with the passive and active loads on the two end spans.

The greatest strain at the centre on either of the end spans will be when that is fully loaded; and, as above intimated, the greatest strain on the central pier will be when both the end spans are fully loaded, which conditions are not difficult to provide for after a few calculations.

It has been shown, by very careful examination of this subject, that practically, and for useful purposes, the points of contra-flexure in the case we refer to here may be taken at $0{\cdot}25l.$, or at one-quarter of the span distant from the central support.

These data having been determined, renewed and additional calculations are to be made on the same principles as those already explained, to fix definitively the proportions of girders in these conditions.

In cases where it is intended to design a girder according to a given model, or in a style analogous to a given beam, of which the weight is given, there is a very simple method to approximate closely to the weights, strains, and sectional areas of the flanges for the new girder.

If we have a beam 100 feet long, weighing 27 tons, and we wish to construct a similar beam 70 feet long, we shall have,

$$0{\cdot}7^3 \times 27 = 9{\cdot}26 \text{ tons,}$$

for the weight of the beam, and with a load of 1 ton per foot run, we should have 79·26 tons for the distributed load; we can then readily determine the sectional areas for top and bottom flanges, and proceed with a few approximations until we have satisfied our conditions, when we can complete the details.

CHAPTER XIII.

DOCKS, JETTIES, AND QUAY WALLS.

THE Railways to which these pages refer more especially, will generally be connected at one end with the seaboard, or with large rivers, and the works required for loading and unloading and for shipping are of primary importance; any false economy on the subject, which would render these works insufficient for their intended purposes, must lead to very imperfect results, and the development of the traffic on the line must be impeded; space, and the capability of the works must be studied in combination with a wise economy, and as much as possible the plans should be projected with a view to after extension. As regards the plan of a dock, we shall generally be confined more or less as to shape by that of the ground where it is to be constructed; it will be more or less in form of a square, a parallelogram, or a truncated irregular triangle; the former will give most room for the free movement of shipping, but it is by no means so easily served as the triangular form, nor does it admit of every portion of quay wall being so readily made serviceable, and if the last be made sufficiently spacious or trumpet shaped at the end opening out into the river or sea, it will generally be found the most serviceable form.

On the subject of depth of water, we must be guided by the draught of water of the largest vessels, loaded, frequenting the place where the dock is to be made, or its immediate neighbourhood; and we mention the largest more especially because, at the height of the trading season, these generally carry off the principal part of the traffic; these vessels very commonly draw over 23 feet of water. It may be scarcely necessary to observe, that the dock should not be constructed where there is not easy access by a sufficiently wide and deep channel.

Similar rules must necessarily hold good as regards docks in communication with rivers, and in both cases the length, breadth, and depth of locks will depend on the dimensions of the vessels to be admitted; on this subject, therefore, the most certain information must be obtained, before any decision can be come to as regards the depth of the dock. This depth, however, is so grave an element of cost, more especially as regards the dock walls, that all possible conditions require study to ensure a safe economy; where circumstances will allow, and where there is any sound reason to believe that vessels of deep draught will but seldom visit us, we may make the dock of less depth, so as to accommodate the general traffic only, and project a couple of short jetties out into the sea for the accommodation of deep draught vessels; these jetties must be sufficiently far apart, so that whilst the large vessels are lying alongside, the entrance into the dock may be left unobstructed. As numerous examples of dock construction are given in the plates accompanying these pages, it will be unnecessary to say more upon this subject at present.

In laying out the works for the service of the dock, attention must be given to obtain the most easy means of access; to the rails being laid with the view of loading and unloading, so that along the same face of quay wall these operations may be carried on without any obstruction existing on the up and down service lines of rails, or cross-over sidings; to effect this, there must be of course cranes enough, with sufficient sweep. In Europe, docks are now generally supplied with numerous wrought and cast-iron cranes; but in distant countries, we can very well carry on the traffic with the timber cranes which a few years back did the work in some of the largest docks in Europe, and are indeed existing in many places still. Where mooring-posts can be got in without interfering with the trains, this should be done; they should generally be some fifty feet apart; when too numerous they are generally more in the way than otherwise.

When we can afford it, the walls should be coped with stone, but when our means are limited, we may cope with half balks of creosoted timber, which will answer very well for many years where the dock is served by rails.

The setting out of dock works, the measures to be adopted as regards construction, and the management of the excavations, always require special care. When the natural surface of the ground where the dock is to be constructed, is at or below high-water mark, it will be necessary to construct a bank with a puddle core continued down for some three or four feet, according to the nature of the soil, below the surface, in order to protect the works during construction.

It is very customary to carry on the excavations by a trench, at first round the site of the quay walls, and to work inwards towards the central portion of the dock; this first excavation may be some 6 or 7 feet deep, with a bench, care being taken to have roads, at least at first, for the barrow wheelers; by following this course we adopt the most economical means towards excavating and disposing of the first 2 or perhaps 3 yards of depth of excavation.

Whilst this work is proceeding, measures are being taken towards proceeding with the masonry, and as such work is always more or less considerable in dock construction, as regards stone, brick, concrete, mortar, and timber, the preparations involve cost and time; measures are also taken as regards wells and establishment of pumping machinery, which must often be powerful to keep the excavations clear of water.

Where masonry only is employed, there are two different modes of building the dock walls, which, in the one case, is a massive retaining wall, of stone or brick throughout, or with a basement of concrete faced with large coarse masonry, or of piling; in the other case, the retaining wall, *per se*, is very slight, and strengthened by piers in front, over which arches are turned; the works of both styles of dock wall are illustrated by working drawings in the plates of docks 81 to 86.

Where the face of the wall is plain, a trench is excavated *in situ*, with the face of the excavation true, as nearly as possible, to the back of the wall, when the earth cut through is sound, in order to save extra filling in concrete; but where there is a want of stability or soundness, the earth at the back of the wall has to be excavated and dry filling got in; this very often considerably increases the amount of cutting. Shoring up is often necessary, even when the trench is excavated forward of the masonry, only in sufficient extent to be a little in advance of the bricklayers or masons; it is but very rarely that it is not necessary to get in concrete foundations, sometimes to a very considerable depth, owing to bad natural foundations occurring in different places; the depth of the trench is increased in proportion, and unless precautions are taken not to cut the trench too rapidly, in advance of the walling, the face of the excavation is pretty certain to fall in, more particularly if there be any water in the ground; it may be unnecessary to observe that as the wall is built up, it must be filled in at the back gradually as it rises in height, and that almost always, where there is any amount of funds, the walling is carried on in several places at once.

A very similar course is adopted where the system of arched dock walling is adopted, sometimes from choice, sometimes from necessity, in order to obtain a wider basis, or to obtain greater leverage for the wall to resist the thrust from the earth at the back. Much will always depend on the nature of the ground, as to whether it be liable to slip, from its nature, or from lying at a high angle of elevation. When the ground will admit of it, the trench for the back wall, arched on the plan, is built first, and the piers in front are brought up simultaneously with it; but where there is cause to fear slips, trenches for the piers are first excavated to the necessary depths, the concrete foundations are got in, and then the brickwork or masonry is built up to the height of the skew backs, for the arches; when this work is completed, or nearly so, the excavation for the back wall is made, the concrete is got in, and then the masonry is built up as rapidly as possible. As the trenches for the piers may be excavated in several places at once, that is, for more than one arch, and the several piers built up at the same time, it is perhaps the most rapid way of doing the work, but it is somewhat more troublesome to obtain a good junction or bond between the piers and the back wall. The walls are then allowed to settle before the centres for the arches are set.

The ground left in front of the dock wall and between the piers may then be excavated.

When the masonry of the piers and of the back wall has well settled down, the centres may be set and the arches turned in the usual manner, and with the usual precautions.

It may not be observed that. considerable and much more than usual care is required in setting out such work, both as regards the lines and the levels; otherwise, more especially where the works are commenced in several places at once, we shall be getting crooked lines where they should be straight, and we shall also run the risk of getting astray with regard to the level of *net-work*, and consequently with regard to our skew backs, evils which must result in very serious consequences to all parties.

Too much care, therefore, cannot be taken in setting out the work, and keeping the whole well checked, for where such masses of earth are being moved, and often indeed move of themselves, as soon as the work has been carried on to some extent, it is not sufficient to rely one day on lines and levels which have perhaps been set out a month or two before.

As general principles, a centre line should be carefully set out first with the theodolite, and the stumps carefully measured in; as many "*dead men*" as possible should be allowed to remain around these as long as may be; from this primary base or central line, secondary ones should be set out, all lengths being most carefully measured, and all angles carefully set off, checked, and calculated; from these secondary lines, those from which the faces of the masonry are to be set off, may then be got, and should be checked two or three times before they can be considered as correct; where the system of piers and arches is adopted, unless the distances are very accurately set out, we shall be getting spans of different lengths where all should be alike, and even when the discrepancies only amount to a few inches, even these will be sufficient to involve difficulties as to the centres for the arches.

It will be needless to observe that docks of the character here referred to must, of necessity, be very expensive works, although of course most durable, or that much more economical docks, of a very useful character, may be entirely or in part built of timber, by means of piles tied in by iron tee rods to land piles driven behind them, with the heads of the land piles some feet below the surface. The same may be observed as to quay walls either facing a river or for sea works, but it is indispensable that all such timber should be thoroughly and effectually creosoted.

Where circumstances admit of it, more particularly in the non-tidal waters of the Mediterranean, jetties built of timber are most serviceable works in lieu of docks, but the works for these are of so simple a character, that nothing further need be said as to their construction beyond what has already been observed in the specification, and we shall merely make a few more remarks on the subject of creosoting, the merits of which, although fully appreciated in England, do not appear to be so well understood abroad.

The value of creosoting timber has become fully admitted by the French as well as by English engineers, more particularly for timber used in the permanent way and for harbour works, when the work is thoroughly carried out. Large timber piles used in harbour works, *unprepared*, have been exhibited on several occasions to show that they had been completely eaten away by the worm to the depth of four or five inches in four years, whilst similar piles, but *thoroughly creosoted*, which had been driven by the side of those which had been eaten away, were completely sound and untouched. At a meeting of the Institute of Civil Engineers in January, 1853, the President, the late Mr. Rendel, produced some specimens of timber which had been attached to the worm-eaten piles of the Southampton Pier, the waters at which place are much infested with worm. Some of these specimens had been left unprepared in any way, and some had been creosoted, and they had been attached to the pier in 1848, below the level of high water spring-tides; when submitted at the Institute, the specimens showed that whilst the timber which had been creosoted had not been touched by the insects, all the other wood had been honeycombed into a mass of disintegrated fibre.

At Lowestoft harbour equally favourable results have been obtained; it was found here that there was no instance of a pile unprepared being sound, all having been attacked by the "Limmoria" and the "Teredo" to a great extent, and some eaten through; but those which had been creosoted, and after four years' immersion had become covered with vegetation, which is well known to attract and afford harbour to the worm, were perfectly sound and untouched by the worm. This extraordinary fact is attributable to the creosote remaining intact in the timber, either wet or dry, and to its destructive properties on animal life. The action of creosote on the teredo has been rendered still more manifest in this harbour in one particular instance; a piece of creosoted timber had been half cut through for a mortice which had not been filled up again, and a teredo had there penetrated a little way into it, and had then attempted to turn to the right and then to the left, and ultimately left without proceeding any further.

In the waters of the Mediterranean in the East, the attacks of the worm are more rapid and effectual than in Northern Europe; the author has seen timber destroyed to a depth of three inches in much less than one year after immersion; a great number of the cells being little less than one inch in diameter.

The inhabitants of the towns on these coasts are perfectly aware of the utter futility of the construction of sea-works with timber *only*, and but very rarely make any attempt of the kind. When from want of means it has been done, the work is very soon destroyed. Neither do they fail to point out the fact to strangers who may think of any such construction. The plan they almost invariably adopt themselves for their wharves or quays is the following:—

A very rough and light kind of camp-shed piling is first got in, behind which narrow boxes are sunk of a depth depending on the depth of water; these are filled with a concrete made of broken stone, lime, and Santorine earth, which is a natural Pozzolana, and the wall gradually carried on up to the water line, above which it is of the usual rubble. The writer of these pages has on several occasions seen quay walls built in twenty feet water by these means only; in the Eastern parts of the Mediterranean they are ordinary works, and commonly built for about thirty-five shillings and two pounds per cubic yard.

Circumstances on one occasion led the author to examine, for the length of a mile or two, the timber of which these framings, or rough caissons were formed, and, without exception, he found that in two or three years the woodwork had been so completely honeycombed by the worm that he could thrust his hand into it and tear large pieces away; it is on muddy shores more particularly that the teredo worm abounds.

The necessity and importance of thoroughly creosoting all timber for harbour-works in these waters is so perfectly evident, that the writer would not have insisted so much on the subject, if it were not for the fact, that it has been neglected where it ought to have been done.

This subject is of an equally grave character as regards the sleepers of the permanent way, and Mr. Bethell's method of creosoting timber is quite as important on this subject as it is for the timber of harbour works. Indeed, in the East it will be found that the action of the climate is much more powerful in inducing the decay of timber sleepers than it is even in these countries, and when uncreosoted they generally show marked signs of decay after twelve months' use.

"The plan invented by Mr. Bethell is for the use of a material obtained by the distillation of coal-tar.* This material consists of a series of bituminous oils, combined with a portion of creosote; this latter substance being acknowledged to possess the most powerful antiseptic properties. The action of this material may be thus described; when injected into a piece of wood, the creosote coagulates the albumen, thus preventing the putrefactive decomposition, and the bituminous oils enter the whole of the capillary tubes, encasing the woody fibre as with a shield, and closing up the whole of the pores, so as entirely to exclude both water and air; and these bituminous oils being insoluble in water and unaffected by air, the process is applicable to any situation. So little is this oil affected by atmospheric change, that the writer has seen wrought-iron tubes that had been merely painted over with it, and laid in a light ground one foot beneath the surface, taken up after twenty years, and they appeared and smelt as fresh as when first laid down.

"By using these bituminous oils, the most inferior timber, and that which would otherwise soonest decay, from being more porous and containing more sap, or being cut too young, or at the wrong season, is rendered available. This will be readily understood when it is considered that this porous wood will absorb a larger portion of the preserving material than more close and hard woods.

"There are two processes in use by Mr. Bethell for impregnating timber with creosote; one is by placing wood in a strong iron cylinder and exhausting the air from it by means of the air-pump, until a vacuum is created, equal to about twelve pounds on the square inch; the creosote is then allowed to flow into the cylinder, and afterwards a pressure is put upon the creosote by a force-pump, equal to about

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* From a paper of Mr. G. E. Clift, read at the Institute of Mechanical Engineers.

150 pounds on the square inch; the timber then taken out is fit for use.

"The second process is by placing the timbers in a drying-house, and passing the products of combustion through it, thereby not only drying the timber rapidly, but impregnating it, to a certain extent, with the volatile oily matter and creosote contained in the matter given off from the fuel used to heat the house. When the timber is taken out of this house, it is at once immersed in hot creosote in an open tank, thus avoiding the use of a steam-engine or pumps."

Specimens of creosoted sleepers, ten years in use on the North-Western Railway, near Manchester, were still perfectly sound and unchanged; also specimens of piles from Lowestoft harbour, which had been in the sea for four years, and continued quite fresh and sound and without being touched by the worm; and also specimens of piles uncreosoted, from the same situation, which were completely eaten away and honeycombed by the worm in the same period.

Mr. Bethell, the inventor of the system, has observed that the presence of moisture in the pores prevented the absorption of the creosote; after drying timber for fourteen days, he found that every cubic foot of timber lost three pounds in weight. He also found, after having introduced the improved drying-house, that in Scotch sleepers every cubic foot lost eight pounds by drying, and afterwards absorbed an equal weight of creosote. An average of 11½ pounds of creosote per cubic foot was now put into all the Memel timber used in Leith harbour, under a pressure of 180 pounds per square inch. It is found that, as far as any process of decay is capable of interfering, creosoted sleepers are better after being in use for eight or ten years than when they were new, the creosote having consolidated and rendered the timber hard. Every piece of timber is required to be increased in weight by the process ten pounds per cubic foot.

THE END.

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